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ABSTRACT

This publication is a collection of solar heating ideas for the do-it-yourselfer. The ideas are presented in a clear, simple and sometimes amusing way. Although written for homeowners, these ideas may be used in businesses and schools as well. Some ideas may make good student projects. The suggestions are illustrated and their costs and probable effectiveness are given. These simple, non-technical solar energy ideas range from making and installing flexible insulating curtains and from installing passive solar heating window boxes to building an active solar trickle-type heating system and to constructing a pumped solar water heating system. A bibliography and a glossary are also included. (MR)

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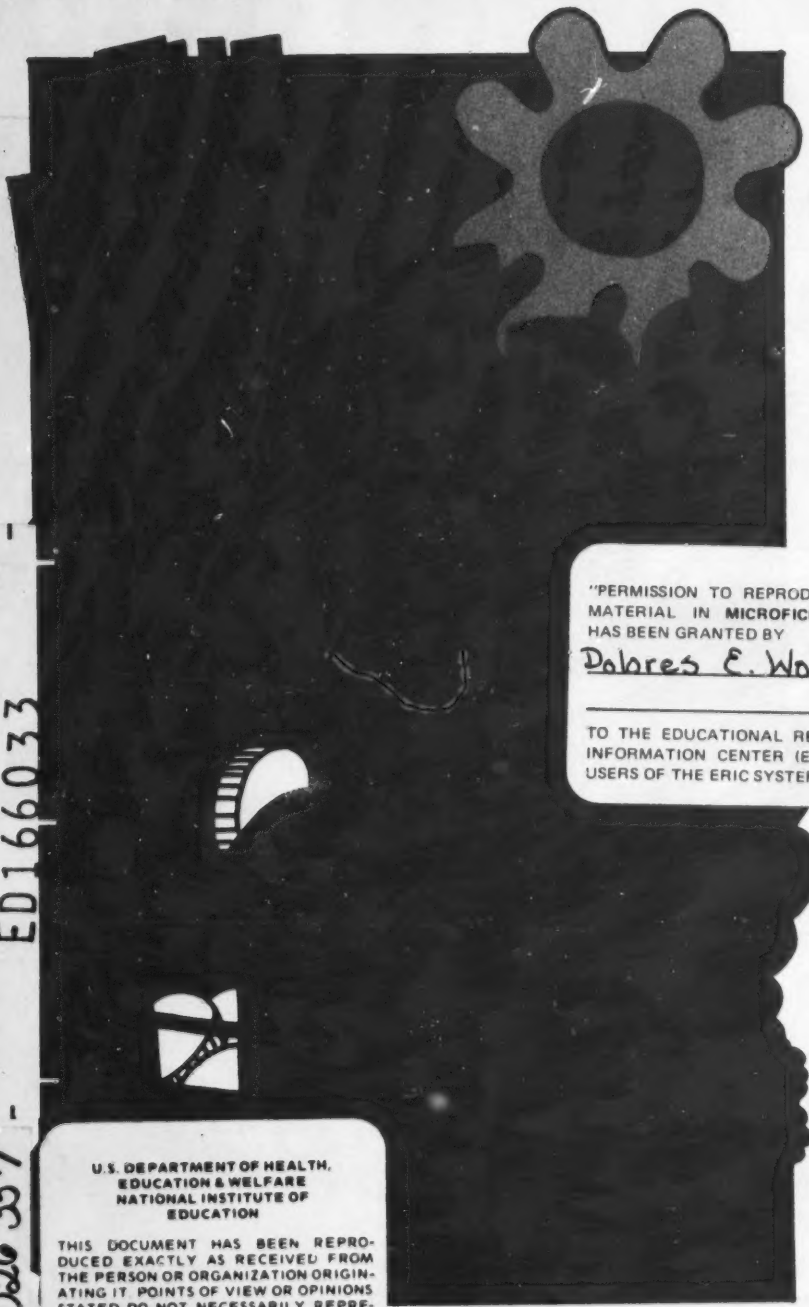

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The Northwest New Jersey Community Action Program (NORWESCAP) is a private nonprofit organization primarily funded from state and federal agencies to provide needed social services for the residents of Sussex, Warren and Hunterdon counties in New Jersey. With housing a major concern, NORWESCAP's Housing and Community Development program started a home winterization project to repair and replace parts of homes for area residents who are unable to do this work themselves. This book originated with a report TEA, Inc. produced to enable NORWESCAP's inclusion of solar energy in the project. This original report was funded through NORWESCAP by the Community Services Administration.

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Foreword

> "If you are not buying or building a new house, there are still many ways to harness solar energy and slash skyrocketing fuel bills. A number of these solar heating projects are within range of the average home handyman or woman."
>
> Bruce Anderson, **The Solar Home Book**

The sun shines on us all, old and young, rich and poor alike. Its energy is plentiful, harmless and free, so it makes good sense to use it. In finding ways to use solar energy you will not only reduce your fuel bills but help solve one of the most urgent problems of our time.

Using solar energy to help heat your house is relatively simple. The best solar collector in the world is a south-facing window, well-fitted and covered with an insulating panel at night. One frequently hears that the cost of using solar energy is still prohibitively high, but this cost comes down considerably when you do the simple jobs — eliminating labor costs and expensive technology. This pamphlet describes solar energy systems that can be constructed at moderate costs and as do-it-yourself projects.

To perform well over long periods of time, these systems are simply-constructed, durable and straightforward in operation. Many systems require you to participate directly in their day-to-day operation, rather than relying on complex and expensive controls. Most of these devices are self-contained and do not tie into existing heating systems. They can be *retrofitted* to a wide range of existing buildings. Because of its origin as a NORWESCAP project this booklet addresses the homeowner and many references are made to "your home," but the measures work just as well in business premises or industrial buildings.

This booklet will not discuss pre-engineered and manufactured products, or solar system components which use expensive parts or fabrication techniques. Devices such as *heat pumps*, metal *tube-in-plate absorber plates*, *heat exchangers* of the sophisticated variety used by engineers, and other "store-bought" solar heating components are too expensive to be considered here. You can find inexpensive substitutes for many of them.

Even with these restrictions a great variety of devices and systems are available. This book includes a variety of ways to use solar energy — ranging from very simple devices to fairly complex systems. You must decide which way best suits your site, your house, your know-how and your pocketbook. Remember that these are suggestions, not blueprints. Before you start many of the projects you should do further reading. There is a complete bibliography at the end of the book.

We hope this kit of ideas will also help you branch out — perhaps even design your own device. The principles involved in solar energy are identical for new and old construction. There is ample room for ingenuity in applying these principles to your specific problems.

Energy Conservation

It is crucial to realize that before considering solar energy you must undertake a comprehensive program of energy conservation. The most cost-effective and sensible approach to the energy shortage is still energy conservation. You can use solar energy as a non-inflationary heat supplier only after instituting common-sense energy conservation measures in your home.

The two most important things to do to conserve energy are to lower your thermostat and winterize your home.

The first method is the more direct. You control the rate of usage with the thermostat. Lower temperatures in the house mean less fuel consumed. It's that simple. Many people (the British are famous for it) can be quite comfortable at temperatures below 68° — they save both money and energy. If you're uncomfortable at those temperatures, insulate your body with a sweater rather than by raising the thermostat. It also makes good sense to lower the temperature at least 5° at night. It's not true that you burn more fuel reheating the house in the morning than you saved overnight. These measures do save energy.

Winterization

Winterization is central to any program of energy conservation. This pamphlet cannot completely cover winterization. It is important, however, to learn some of the most important measures which you can use to winterize your home. A brief approach to winterization is outlied below and may be supplemented by other sources (see Bibliography).

The illustration below shows by percentage the amount of heat loss in three houses of the same size and shape, but with differing qualities of insulation. The poorly insulated house has 100% heat loss, the moderately insulated house has 60% heat loss, and the well insulated house has only 25% heat loss. Heat loss occurs in two ways: infiltration and conduction.

Infiltration

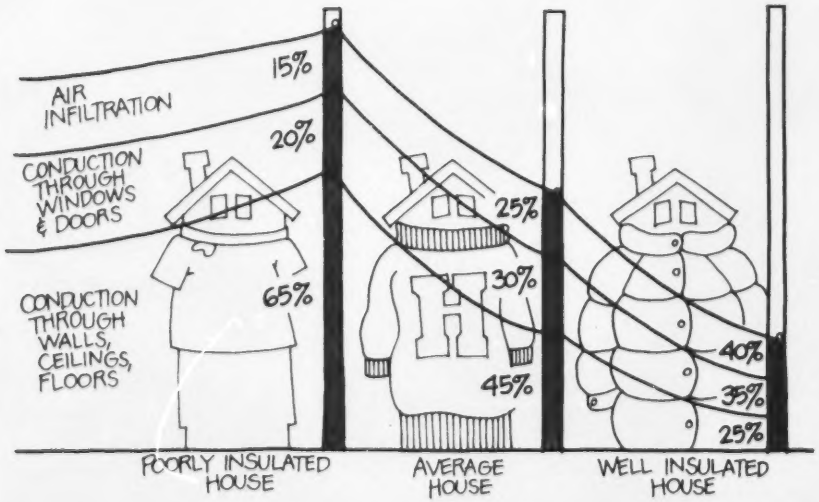
In all the houses, much of the heat is lost through cracks and openings; cold air leaks in and replaces expensive, heated air. This type of heat loss is called "infiltration."

To combat infiltration, first locate and seal any large, obvious holes in windows, foundations, roofs, etc. Next, recaulk smaller cracks around windows and door frames to further seal your home. You can blow cigarette smoke at

your windows to locate leaks. An assistant on the other side can pinpoint problem spots. Next, weatherstrip your windows and doors. This seals the small openings at the bottom, top and sides of doors and windows. These small openings allow a great amount of heat to escape; be sure to take care of them! You can use pieces of cloth, or you can buy special felt or plastic weatherstripping made specifically for this job (available at hardware stores). After you caulk and weatherstrip windows and doors, the most productive step is to add storm windows. This can save from 1/3-1/2 of the heat that infiltration loses through your window. You can find out more about adding another layer of glazing material in the text that follows.

Conduction

Comparing losses in the three houses, the poorly insulated house loses the most heat through conduction. In the best house, conduction losses are dramatically reduced. Conduction occurs when heat passes through building materials, such as wood and plasterboard, directly to the cold outdoors. The best way to reduce conduction heat loss is to insulate. Insulating materials slow the heat flow through walls, ceilings or other surfaces. Attics, easily accessible and one of the greatest sources of conductive heat loss, should be well insulated with at least 6 inches of mineral wool insulation or its thermal equivalent. When possible, use one of the many available methods to insulate exterior walls (if they are not already well-insulated). Use rigid board insulations on interior surfaces or applied to exterior surfaces if new siding is required at the same time. Or, insulation can be blown into walls through small holes cut in the siding and then resealed. Flammable insulation when improperly used can be a fire hazard — so be careful! Some insulations, such as *polyurethane*



foam, are more dangerous than others like *fiberglass*, *cellulose fiber*, or *urea-formaldehyde* foam. Check with local fire officials if you have a question.

You should also make sure that your furnace works properly — clean it periodically so that you receive the most energy from your fuel. To save more energy, you might also consider heating only the areas of your home which you use most in the winter.

Insulation is usually thought of as an important part of walls, floors and ceilings, but people are realizing that insulating over window areas is also very important. Although windows take up only a small percentage of the building surface, the iliustration shows that conductive heat loss through windows is considerable. So windows are an important source of heat loss — but they are also one of the most important types of solar collectors. In the text you will find a number of ways of dealing with this two-sided nature of windows.

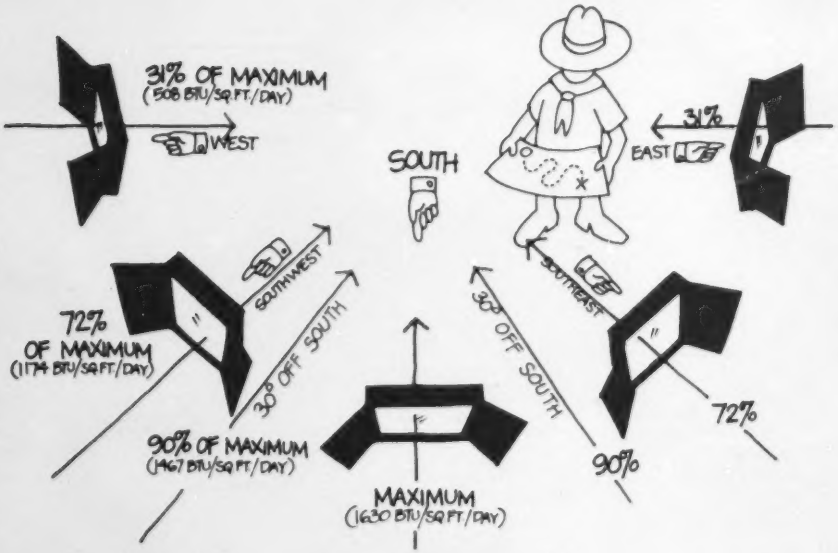
Using all of these measures will significantly reduce overall heat loss in an "ideal house." At this point, infiltration losses are proportionally the largest, because fresh air can't, and shouldn't, be eliminated entirely. Intelligent design minimizes infiltration while providing necessary fresh air.

Solar Energy

Orientation

To "orient" means to correctly position in relation to the environment. Ideally, a solar device should face due south. However, even devices that cannot face exactly south can still be effective.

Many people think that any solar energy collecting surface must face directly south to get any real benefit, but this is not so! From the illustration, we can see how much sunshine is lost for orientations other than south (for vertical wall surfaces located at latitude 40 degrees north). A vertical wall surface oriented as much as 30 degrees east or west of due south, will still receive 90 percent of the maximum solar radiation striking a south-facing wall. Even with a 45 degree deviation from due south, a collector can still catch about 72 percent of the maximum possible radiation striking a south-facing wall. These figures apply to the winter heating season when collecting sunshine is most important. Even walls facing as far as 60 degrees from due south can collect substantial amounts of solar energy. Notice that for due south, 1630 Btu *(British thermal units)* per square foot per day strike the vertical wall in January.



This analysis suggests a substantial leeway in the design and orientation of retrofit devices. If a collecting surface cannot face exactly south, its size can be increased to compensate for the decreased sunshine. In other words, the further the orientation off due south, the larger the collecting surface needed. When there is a choice, direct the collector as close to south as possible, then you will not pay extra for the materials for a larger device.

Tilt

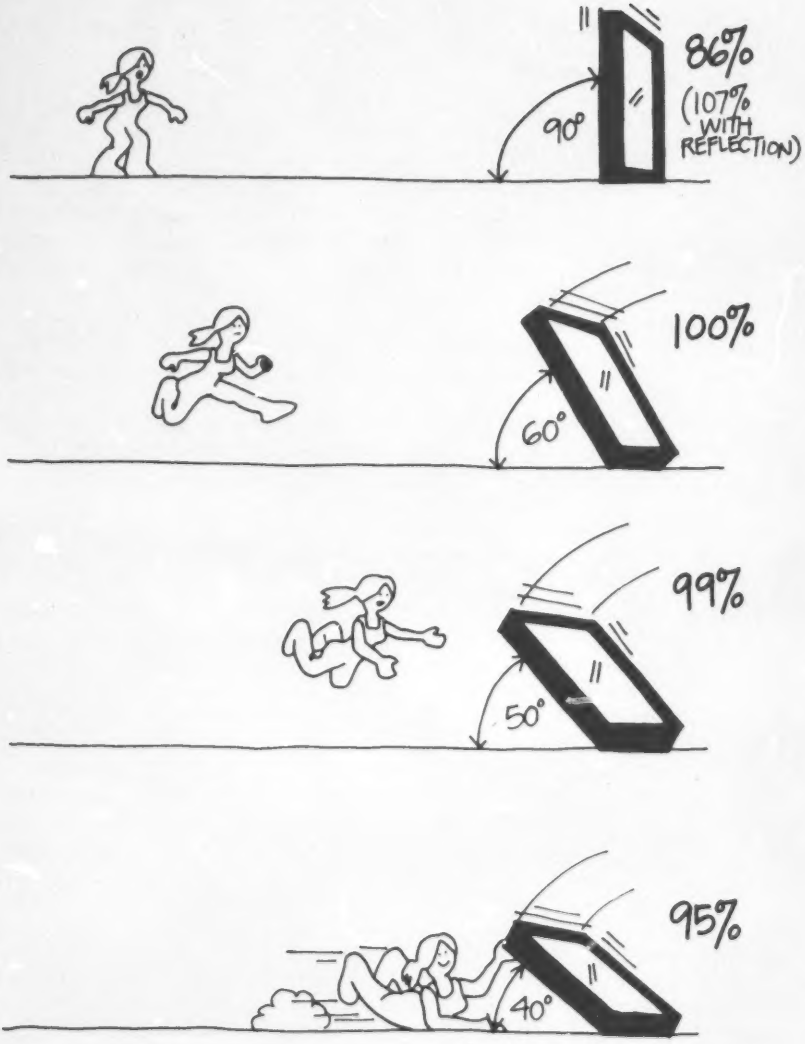
Like the orientation, the tilt of the collecting surface affects how much solar energy can be gathered.

On the basis of 10 degree increments, readings taken per unit area on sunny days in the heating season, indicate that a tilt angle of 60 degrees from the horizontal collects the most solar energy.

Collecting surfaces that tilt away from 60 degrees receive less than the maximum possible sunshine — the illustration shows how much less. For vertical surfaces, performance can be greatly increased by the presence of a reflecting surface such as snow. Therefore, if you are unable to place your collecting surface at an angle, reflection onto the vertical collector helps you collect the available energy. In fact, a vertical collecting surface, combined with horizontal reflection can sometimes collect more energy than a surface tilted to the "ideal" 60 degrees.

These figures demonstrate that tilts as much as 20 degrees to 30 degrees from optimum can still intercept over 90 percent of the available daily *insolation* per unit area. From a practical viewpoint, this suggests a considerable leeway in the design and disposition of retrofit devices.

You may have many reasons to build or use a surface with less than optimum tilt or orientation. If the device is part of, or attached to an existing building, you must use the surfaces you already have. A free-standing device can be more flexibly placed, but other things may interfere — trees, neighbors' houses, even hills may block the ideal orientation. Or it may look too obtrusive to have a large solar device sitting at an odd angle. As our figures demonstrate, if the collecting surface cannot tilt or face in the "ideal" direction, the decrease in solar collection need not be excessive. Your own good judgement will guide you in choosing the best angles for particular situations.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A Kit Of Ideas

The ideas in this kit vary widely in complexity and cost. Some projects may cost little or nothing, if you already have the supplies on hand, others may amount to substantial investments. At this point you must consider the cost-effectiveness of each project — how much energy (and money) can you save for each dollar you spend. Within each section there is a progression from simple projects to more complex ones. Cost-effectiveness usually parallels that progression. The simpler ideas are often more cost-effective. The complicated ones may offer the same fuel savings yet cost a great deal more.

In order to give you an idea of the relative merits of each idea from the point of view of energy saved per dollar spent, the last items in the discussion of each idea are "Materials Costs," "Fuel Reduction," and "Cost-Effectiveness." The costs are those for the necessary materials, assuming you have to buy most of them. No cost for labor is included as most of the projects are feasible for the do-it-yourselfer.

The fuel reduction is given in terms of oil. Your actual saving will depend on the present and future fuel cost. If you use electricity, 30 kilowatt-hours (kwh) of *electric resistance heating* is the equivalent of one gallon of oil heat. Thus, if your electric company charges $.04/kwh, the equivalent of one gallon of oil would cost you $.20. In reality, electric costs are often higher than that. To find your local equivalent price of electricity, multiply the rate per kilowatt-hour by 30. If you use natural gas, 125 cubic feet of gas is the equivalent of one gallon of oil. To get the equivalent cost of the natural gas, multiply the charge for 100 cubic feet (1 ccf) by 1.25. If you use bottled gas, which sells by the pound, use 4.5 pounds of gas as the equivalent of one gallon of oil. The equivalent cost of the bottled gas can be figured if you multiply the price per pound by 4.5.

All fuels are expected to continue rising in cost, although estimates vary as to how much. You may want to include some estimate of such price inflation in your calculations of energy saving over the years.

At the end of each discussion is an oil barrel diagram, which shows the relative cost-effectiveness of each idea presented. The amount of oil left in the barrel represents the amount of energy saved relative to the amount of money spent. Therefore a high level indicates that not much money need be spent to save a lot of energy. A low level indicates that not much energy is saved for the amount of money spent. The cost-effectiveness ratings on a scale of 1-20 correspond to the levels in the barrel.

The ideas are presented schematically, with discussions of advantages, disadvantages and variations. Construction details are not given because there are so few "typical" situations in retrofitting. The Bibliography at the end is intended to lead you to more detailed information than can be given here. It is recommended that you seek this additional information, particularly for the more complex and expensive projects, before you invest a great deal in getting started.

Flexible Insulating Curtain

As stated earlier, a window is the most efficient solar collector. After entering a room through a window, sunlight (solar energy) should be put to the best possible use. Yet once solar energy enters and heats the room, the easiest way to lose heat is back through these same windows. One way to prevent this is to cover all windows with insulating curtains when the sun has stopped shining.

It is important to tightly fit the curtains to eliminate the movement of warm room air between the cold window surface and the closed curtain. The curtain should attach securely at the top, sides and bottom. A fixed valance (see illustration) is the best way to get a snug fit across the top. A vertical valance is one way to attach it along the sides. Make sure that you weight the bottom of the curtain, or in some way make it airtight along the floor.

Variations

- Curtains can be constructed to roll up and be secured at the top of the window during the sunshine hours. *Velcro®* strips along the sides will keep the curtains tight and draft-free at night.
- Curtains made of heavy quilts, multi-layered fabrics, or quarter-inch flexible foam insulation covered with your choice of fabric, or any other material will prevent excessive heat loss.
- One of the best insulating curtains uses several layers of material which traps air between each layer.

Where This Works

Insulating curtains can be used in a wonderful variety of situations. Any window (with some room around the edge) is a prime target for insulation curtains. To maximize the benefit from your curtain, make sure you first seal any cracks or leaks in the existing window and its frame.

Advantages

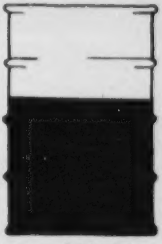
- An insulating curtain is the easiest way to change an energy-collecting daytime window into an energy-conserving nighttime window.
- Insulating curtains are simple and inexpensive; they offer significant fuel savings for anyone willing to spend the time.
- Because it is a simple indoor device, your insulating curtain should have a long lifetime — reducing your fuel bill all the while.

Disadvantages

- You must be willing to open and close your curtains every day to reap maximum benefits. If you get lazy you don't save as much energy (and money) as you could.

- When open, the curtain takes up wall space. In some cases there may not be enough wall space around your window for the curtain.
- A flexible curtain will not be as tight or as well insulated as a rigid shutter (see next section) yet could cost as much or more.

Economics



Materials Costs: The materials can cost from $1 to $2 for each square foot of your curtain. Therefore, it will cost from $10 to $20 for a 10 square foot window. If you use elaborate materials this figure could be higher.

Fuel Reduction: For each square foot of window-surface covered each night with a flexible insulating curtain, the savings is from ⅛-½ gallon of fuel oil each heating season. A 10 square foot curtain will save from 1-5 gallons per year.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 10-14.

Rigid Insulating Shutters

An insulating panel placed over a window in the evening considerably reduces heat loss through that window. This heat is either gained through the window during the day or produced expensively with your oil burner. It is just too precious to throw away. So keep it in — with an insulating shutter. You must be able to open the shutter during the day and close it at night.

You can make an insulating shutter from 2 inches of styrofoam surrounded by a wooden frame and mounted to the wall with hinges. Most shutters need a wood frame for strength as well as mounting purposes. The most valuable shutter would have an insulating value equivalent to the wall next to the window. Besides insulating a window at night, a tight-fitting shutter will also cut down on cold air leaking into the house around the window's edges. Weatherstripping along the edge of the shutter will help seal it tighter.

The biggest design issue is where the shutter will go when it's not covering the window. This might vary from room to room. See "Variations."

For the money, this is an extremely worthwhile energy saver.

Variations

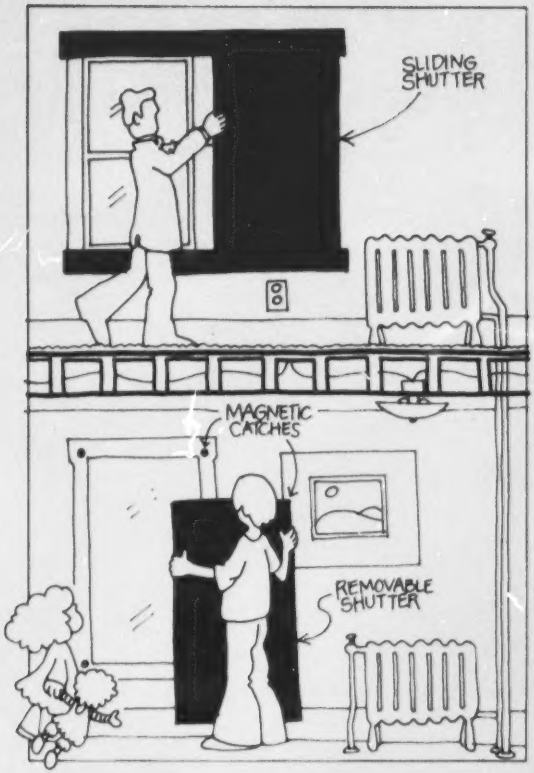
- Many materials and thicknesses are possible. The easiest are 1 and 2 inch-thick boards of rigid styrofoam; the greater the thickness, the greater the energy-savings. Instead of rigid foam plastics, fiberglass or other insulating materials such as urea-formaldehyde foams can be used.
- Shutters can be mounted on sliding tracks across windows, hinged up or down, sideways, or any way you like. Try hinging the shutter along the bottom edge and fold it down during the day to make a table.
- The hardware used to support the shutters can range from continuous cloth hinges to fancy hardwood frames with piano hinges. Weatherstrip along the edges and place latches at top and bottom to pull the shutter snug with the window frame. For lightweight shutters, you can use magnetic catches, as in the illustration.

Where This Works

These inside insulating shutters are most appropriate in cold, freezing climates where snow and ice would accumulate on outside mounted shutters.

Advantages

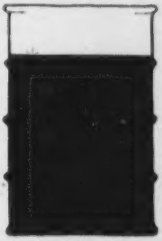
- A good shutter provides effective insulation for the windows — where it's needed most.
- Shutters are easy to make and operate, requiring no fancy tools or mechanisms.
- A tight-fitting shutter greatly reduces cold air drafts around windows, making the house considerably more comfortable.



Disadvantages

- One problem is condensation. Since the glass is on the cold side of an indoor shutter, water vapor which works its way from the inside of the house out through the shutters will condense on the glass and wet the framing around the window. Due to the tight seal around the shutter, the problem is more severe for shutters than curtains.
- Some plastic foam boards are fire hazards and may produce toxic gasses when ignited. Therefore, they are safest when covered with a fire-proof material. Check with local fire code officials for their recommendations.
- In the open position, or when removed, the shutter takes up space.

Economics



Materials Costs: There are a variety of ways to build a shutter, but costs should range from $.70 to $2.50 per square foot. A 10 square foot shutter would, therefore, cost between $7.50 and $25.

Fuel Reduction: If used every night, an insulating shutter of about 10 square feet (an average window size), made of 2 inch styrofoam will save you up to 7½ gallons worth of oil heat every winter.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 15-16.

INSIDE STRUCTURES

Thermal Mass

So far, this booklet has offered ways to make houses better collectors and conservers of solar energy. A house can also store heat for later use. You can make your house store heat if you place a substantial amount of heat-holding material such as masonry, concrete or containers of water in the building where the sun can shine on them. This *thermal mass* will also help to prevent the sunny room from being overheated, and will reduce the need for opening windows or shading out the sun's free energy just to maintain comfort. At night, this mass will re-radiate its stored solar heat and reduce the need for conventional heat.

There are many ways to provide thermal mass to a room. The trick is to get enough material. Try to provide 2 to 4 gallons (¼ to ½ cubic feet) of water per square foot of south window, or ½ to 1 cubic foot (75 to 150 lbs.) of concrete or masonry per square foot. If the mass is not in direct sunlight, double or triple these amounts. If you have a concrete slab, you have thermal mass — just allow the sun to reach it. The mass should be dark-colored to absorb radiation and should be placed as close to the window as possible to get the sunshine all day long.

Variations

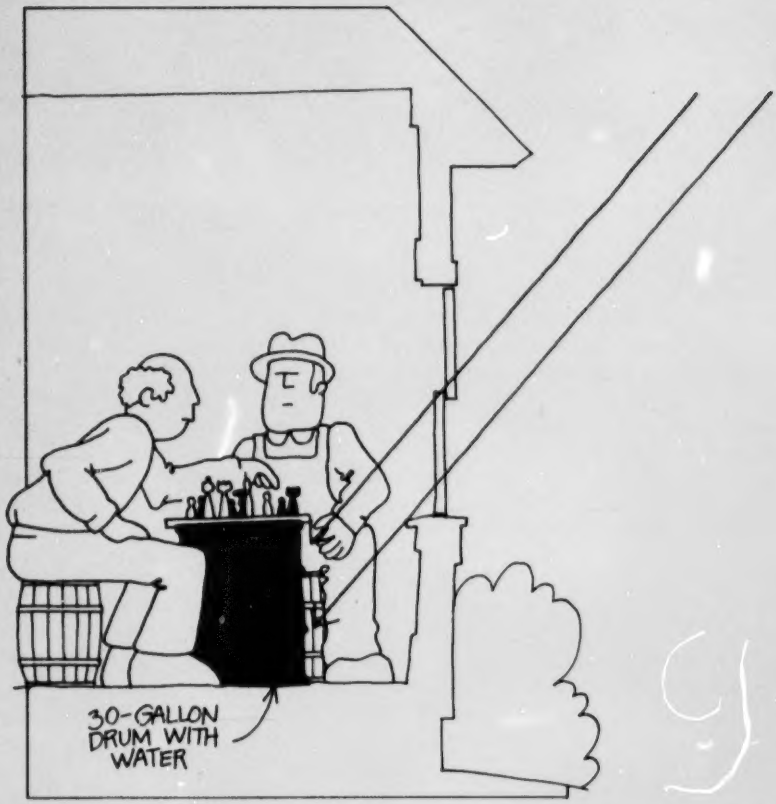
- If you have a strong floor, you can pour a thick 2"-4" concrete slab over it, or lay down brick or heavy tile.
- Steel drums or racks of water-filled containers could act as partitions or furniture.
- An interior wall that receives sunlight could be lined with stone or brick.
- Thermal mass in shady areas will also help by moderating temperatures. When you lower your thermostat at night, the mass stays warmer for several hours — keeping the space warm too.

Where This Works

Adding thermal mass is best for rooms with lots of southern sun (especially those that overheat). The thermal mass must be placed in unobstructed sunlight for as many hours a day as possible.

Advantages

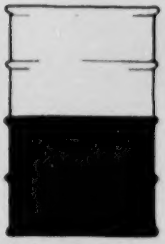
- The addition of thermal mass does not increase the amount of solar energy available to a space, but it lengthens the time over which you can feel this heat.
- Thermal mass moderates temperature swings between day and night — keeping the space more comfortable.
- Excess heat that might otherwise be thrown away is saved and used later.
- Thermal mass has no moving or complex processes. It simply sits there and does its job — without your time or effort.



Disadvantages

- Thermal mass requires bulky materials and often requires a lot of space.
- The structure of your house will most likely need strengthening before it can support the considerable weight of thermal mass. To be sure, have your house checked before you load in the mass.

Economics



Materials Costs: Thermal mass materials are common and inexpensive. Concrete runs $27 to $30 per cubic yard (27 cubic feet). Water is almost free. Containers, such as steel drums or plastic jugs, can be scrounged or bought second-hand. Figure $.40 to $1 per square foot of window area.

Fuel Reduction: Thermal mass reduces fuel consumption only in that it makes the solar energy available through your windows more useable. If the windows don't overheat the space, the mass won't help, except by moderating uncomfortable temperature change. On the other hand, under good conditions, thermal mass will save from 1/10 to 1/5 gallons of oil per square foot of south window per heating season.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 9-11.

Additional Glazing

A second, or even a third, layer of glass or plastic added to a window is usually called a storm window. Most windows save energy in two ways. They admit sunlight (solar energy) into the living space, and they reduce the flow of outgoing heat by blocking the movement of heat. When you add a second or third layer of glazing, you reduce the transparency of the window, but, more significantly, you increase the insulating value of the window by creating dead air spaces. In other words, with additional glazing, less heat moves from your warm room to the cold outdoors.

A third layer will save almost twice as much energy as adding only a second layer. A layer can be as inexpensive as possible. Most importantly, the layers must be installed tightly to keep out drafts.

These second and third layers of transparent materials can be made easily by stretching plastic over a light frame. Ideally, they should be weatherstripped or caulked for air-tightness. Be sure to leave small "weep holes" at the bottom of the storm window so that any inside condensation can drain away. You may want to provide larger holes that can be uncovered occasionally for extra ventilation.

The most permanent solution is to use glass in wooden or metal frames which can be stored and reused for years. You may be able to buy or scrounge second-hand storm windows that fit. If not, having new ones made is a good investment.

Variations

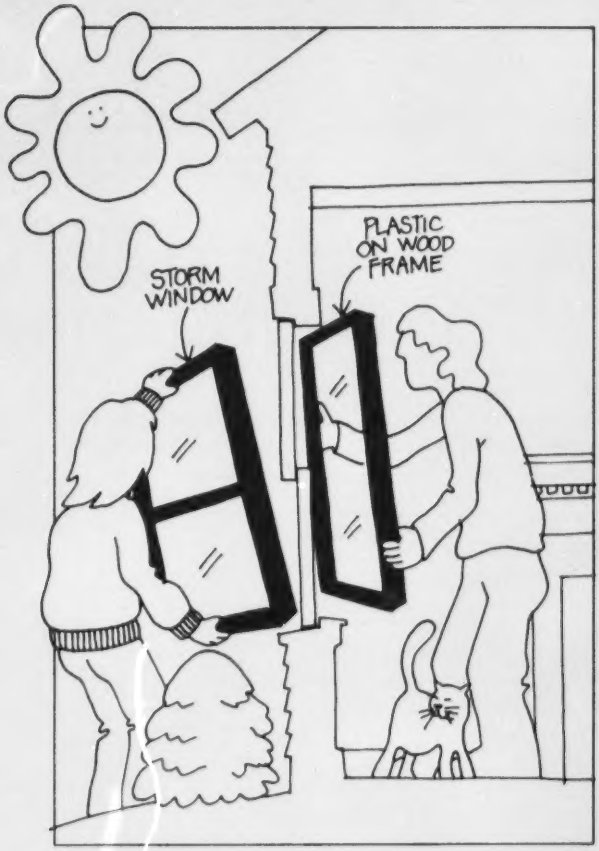
- An even cheaper method is to tack or staple plastic film directly to the window frame. This, however, is neither exceptionally durable, nor attractive.

Where This Works

This solution can (and should) be applied to all windows. If you can't do them all at once, do the north windows first and work your way around the west and east sides to the south side. During the winter in the Northern Hemisphere, the sun almost never penetrates windows on the north. Therefore, north-facing windows provide no solar gain, and actually lose significant amounts of heat. Insulate them first!

Advantages

- Additional glazing is relatively cheap and saves lots of energy.
- It's easy to install and applicable to all window types and locations.
- It insulates the area of greatest heat loss in your house, while allowing sunlight to shine in.



Disadvantages

- You may have to install or remove additional glazing in the spring and fall.
- It may interfere with the opening of the window for ventilation or view.
- A plastic glazing will blur the view.

Economics

Materials Costs: The materials for adding a second or third layer can cost from $.25, if you scrounge, up to $3 per square foot for custom-made, store-bought units. If you make them yourself, the maximum cost will probably be $1.50 per square foot. For a 10 square-foot window, the cost will be $2.50 to $30..

Fuel Reduction: Putting a second layer over a square foot of window can save from ⅓ to 1 gallon of fuel oil per heating season. A 10 square foot window will save from 3 to 10 gallons per winter. A third layer will save somewhat less than twice that amount.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 17-20.

Existing Stone-Masonry Walls Transformed Into Solar Collectors *

This scheme converts an existing stone, brick or concrete south-facing wall into a combination solar collector and solar heat storage unit. First paint the southerly wall a dark color. Then make openings through the wall at floor and ceiling level. Cover the outside of the wall with glass or durable clear plastic, leaving a space between the wall and the glass. (Double glazing will provide more energy savings than a single pane.) That's about it! The sun shines through the glass and heats up the wall. The wall conducts some of the heat into the house. It also heats up the air in the space between the wall and the glass. The air rises and enters the room through the ceiling opening. This process draws cool air out of the room at the floor level. The wall also stores some heat for nighttime use.

Here are some details about the openings in the wall: make them 2 to 3 feet apart at floor and ceiling level. Each opening should be around 8 inches in diameter. They can also be rectangular. Include dampers, or little doors on the openings. Close the bottom ones at night during the winter to prevent cold down-drafts. Close the top ones during the summer to keep out the heat. Provide a vent at the top of the space between the wall and the glass. Open it in summer to let hot air out — preventing collector overheating.

Variations

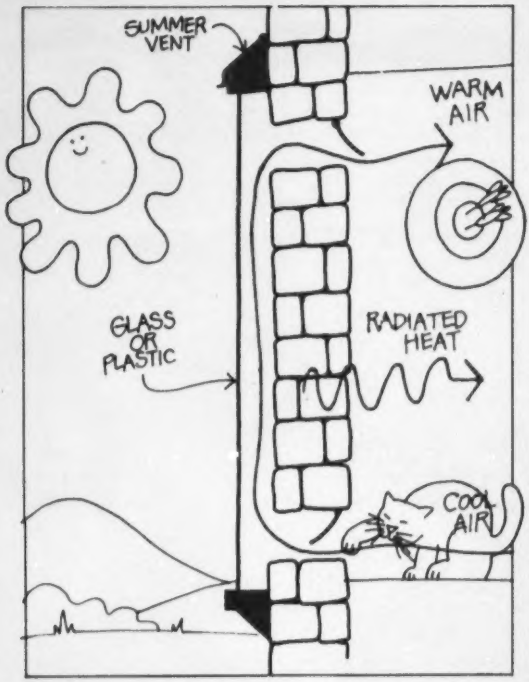
- Cover the glass at night with insulating panels and greatly reduce nighttime heat-loss through the wall. You can slide the panels on tracks, or hinge them like big doors.
- For uninsulated walls, build the system but do not make the openings. This vent-less system saves just half as much energy as the vented system. This is because the heat would have to soak through the wall in order to heat the room. If the wall is insulated, the openings are necessary.

Where This Works

This type of solar collector works well over uninsulated south-facing stone, brick, block and concrete walls that have a living-space directly behind them. They work exceptionally well over fully exposed concrete basement walls or on existing stone houses.

Advantages

- This system converts heat-losing walls into heat-producing walls. Collections, storage, and heat delivery are combined in one simple unit.

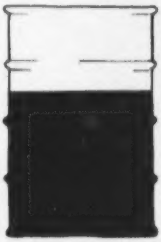


- It also effectively insulates hard-to-insulate walls, while preserving the interior appearance of the wall.
- The system has no mechanical parts; you can control it quite easily.

Disadvantages

- This wall-type solar collector produces less heat when placed over an insulated wall.
- It may be difficult to find wall space where you can easily or conveniently cut the needed openings.
- The collector may not look as attractive as the stone-masonry wall it covers. If the wall is not well-built, the heat of the collector may damage it.

Economics



Materials Costs: It will cost approximately $2 to $4 per square foot for the glass, framing materials, caulking, and dampers for the openings. Add another $.75 to $2 per square foot for insulating panels.

Fuel Reduction: Each square foot of solar wall saves between ½ and ⅔ gallon of oil each winter. Insulating panels, when used at night, will almost double the savings.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 11-14.

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*This scheme was first used in Essex, Massachusetts in the late 1800's. Felix Trombe and Jacques Michel popularized the concept in Odeillo, France ten years ago and it has been widely used throughout the world since.

Roof Air Collector Over Existing Slate Or Metal Roof

This is a design for an air-heating solar energy collector that you can build on an existing, south-facing roof. If your roof leaks and you planned to fix it anyway, you can use this idea to waterproof your roof and heat your house at the same time. The collector is like a glass-bottomed box placed upside-down on your roof. Install strips to support one or two layers of glass or rigid plastic over the roof, and ducts to guide the air between house and collector. Basically, cool air is taken from a cold part of your house and brought to the bottom of your roof through a duct. The air gets hotter as it comes in contact with the roof (which is absorbing the sun's energy). At the top of the roof, a large duct collects the warm air. A fan then blows the warm air back down to your house. A more complicated system can store some of the heat for sunless hours by heating a bin of rocks or small containers of water.

You can use clear fiberglass plastic sheets instead of glass as a covering. Two cover-layers can reduce heat losses but are more complicated to install. Framing for the covering can be spaced two feet apart on your roof. Allow about 2-3 inches of air between your roof and the glass or plastic cover of your collector. Be sure to vent the collector so very hot air can escape in summer.

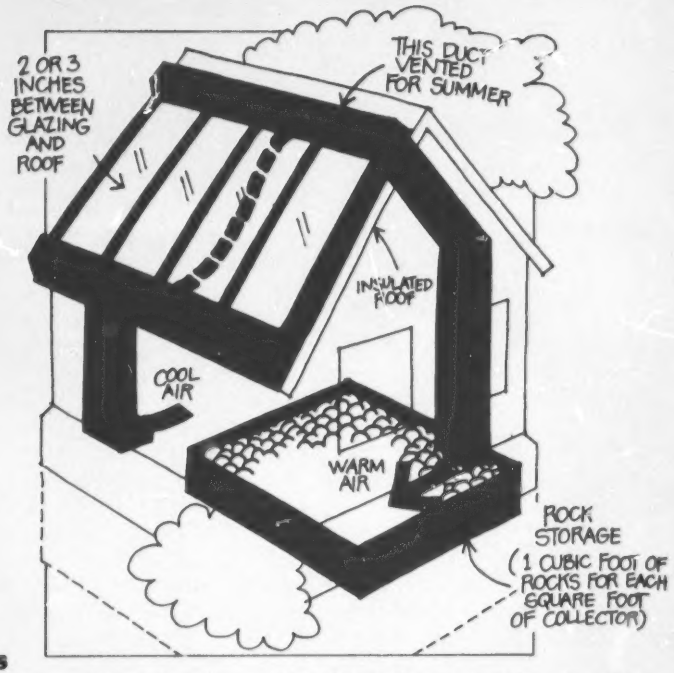
Large ducts are needed to carry all the slow-moving air off the roof. For 500 square feet of roof, the duct must be approximately 1 foot by 2 feet in cross-section.

Variations

- How you build the ducts and the vent will depend upon the construction of your house. The vent can open to the top or side.
- If the rooms requiring the heat are above the collector, then the solar heated air can rise naturally without fans or pumps. This is called *thermosiphoning*, and saves the energy needed to run the fan.

Where This Works

This can be applied to slate or metal roofs only. On other roofs, the surface cannot withstand the high temperatures that build up in the collector. Make sure that your roof can withstand temperatures in the 150-200 degree range. As explained in the Solar Energy section on page 5, a south-facing roof can tilt as much as 40-30 degrees from the horizontal and still collect a large percentage of the available solar energy. Roofs shallower than this would not receive enough sunlight to be effective collectors.


2 OR 3 INCHES BETWEEN GLAZING AND ROOF
THIS DUCT VENTED FOR SUMMER
INSULATED ROOF
COOL AIR
WARM AIR
ROCK STORAGE
(1 CUBIC FOOT OF ROCKS FOR EACH SQUARE FOOT OF COLLECTOR)

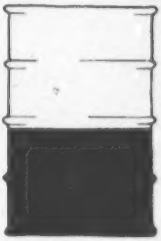
Advantages

- Under certain circumstances, such as the leaky roof mentioned earlier, this can be a very exciting way of doing two chores at once.
- By using the existing roof surface, you save money by not buying collector parts other than the cover and connecting ducts.

Disadvantages

- Expansion due to the high temperatures could damage the roof.
- If your roof is very leaky, the warm air leaking through it may be wasted in an unheated attic space.
- This is not a very efficient solar collector, but it does trap some heat that falls on your roof.

Economics



Materials Costs: The cost will vary, depending on the quality of materials used and on how much alteration your house requires. In general, you can expect to pay $4.50-$7.50 per square foot of collector built. A 100 square foot collector, then, would cost $400-$750. If you add a rock storage bin, this cost naturally increases perhaps as much as 100 percent. If the system is larger than 100 square feet, you will probably need some form of storage.

Fuel Reduction: Each square foot of solar roof air collector saves between ½ and ¾ gallons of oil per season. A 100 square foot collector will save from 50-75 gallons per year.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 9-10.

Add A New Window

Everyone should consider adding a window to the south wall of the house. During the winter a double-glazed southerly window gains more heat energy from the sun than it loses back to the cold outside. Be sure to add a storm window or use double glass such as Thermopane®. Install it efficiently — prevent air from leaking around your new window frame and into the house. Now insulate your window at night with an insulating curtain or movable insulation (such as a shutter) and you have one of the best solar collectors in existence!

Two things to remember: First, be careful when cutting through the wood frame that holds up your house. Consult with a contractor or architect first to avoid damaging the structure. Secondly, when the window is finished, keep the curtains open and let the sun shine in! If you close your curtains in daylight you keep solar heat out of your house. If you want to prevent fading of your upholstery — move the furniture and open the drapes!

Variations

- Your new window can be either fixed or movable. Fixed glass allows less cold air to sneak in, but can't be opened for ventilation.
- Windows come in many sizes and types, from colonial double-hung to bay windows and sliding glass doors.
- Skylights are windows, too. Because hot air rises, it is especially important to have insulating shutters for skylights.

Where This Works

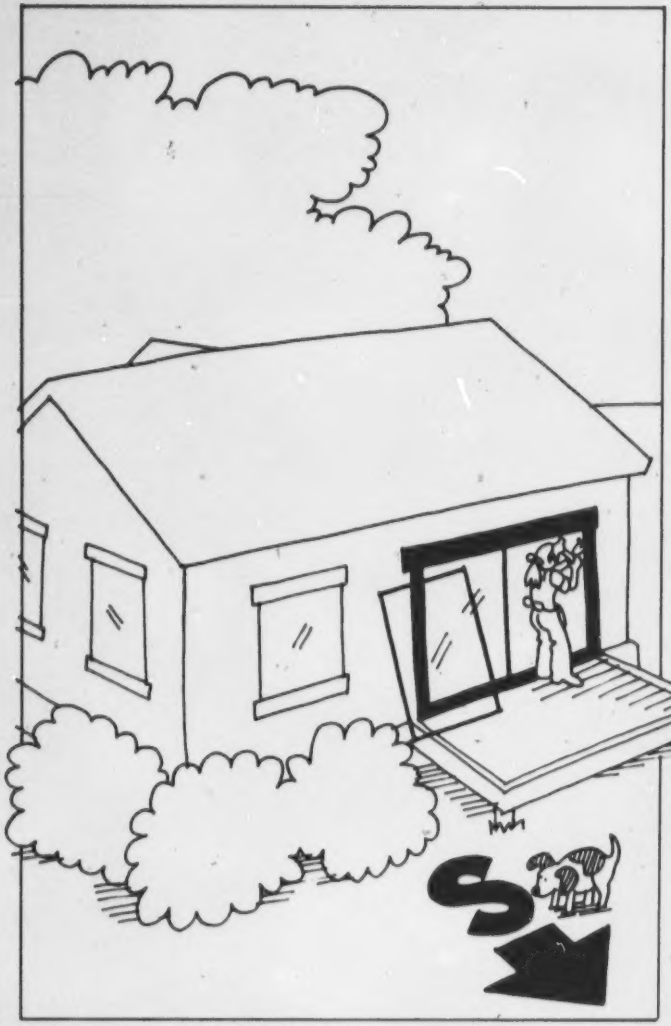
This works almost anywhere on the south side of your building. Just don't cut out something that's holding your building up, and don't cut into electrical wiring or plumbing.

Advantages

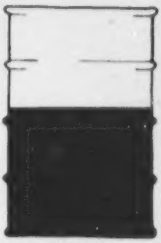
- The advantages of windows are obvious — more sun for your plants, a better view of the world . . .

Disadvantages

- It is possible to get too much heat, especially in the summer, if too much of the south wall is glass. You may have to add materials (see thermal mass page 14) to absorb this excess heat.
- Windows reduce the wall area inside.
- They may tarnish the appearance of the house.
- They cause considerable disruption while being built.



Economics



Materials Costs: A window of regular size (10 square feet) will cost about $50.00. Add the trim materials, reframing, and labor. Bigger windows cost more. Tight, well-weatherstripped windows do too, but it is worth the extra expense to keep out cold air infiltration.

Fuel Reduction: Each square foot of window area can save you from ½ to 1 gallon of oil per heating season. A 10 square foot window will save from 5-10 gallons a winter.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 9-13.

Outside Shutters

An insulating shutter hinges on the outside of your house. It swings open during the day to allow sunlight through the window — at night, the shutter closes to trap the heat inside. For maximum insulating effectiveness, the shutter should close snugly. In summer, when the house overheats, the shutters can be closed or partly closed to keep sunlight out. You needn't open every window to close the shutters. Go outside to do it, or devise a remote-control method of closing.

By lining the inside of the shutters with a reflective material, you can use the open shutters as reflectors — directing more heat-producing sunshine into the house. A reflective foil also reflects heat back into the house when the shutters are closed. On east- and west-facing walls, a reflecting and insulating shutter can bounce southern light directly into the room when direct sunshine is not normally available.

Be sure to design a shutter that will endure bad weather — windy days or snow falling off the roof.

Variations

- Your outside insulating shutters can hinge from the sides as shown or from the top and/or bottom of the window. If you will use them as reflectors and shutters, the kind hinged on top and bottom are most effective on the south side.
- Top hinging shutters can be used as summer awnings.
- Instead of using a hinge, your shutter might slide on a track or be completely removed and stored during the day.

Where This Works

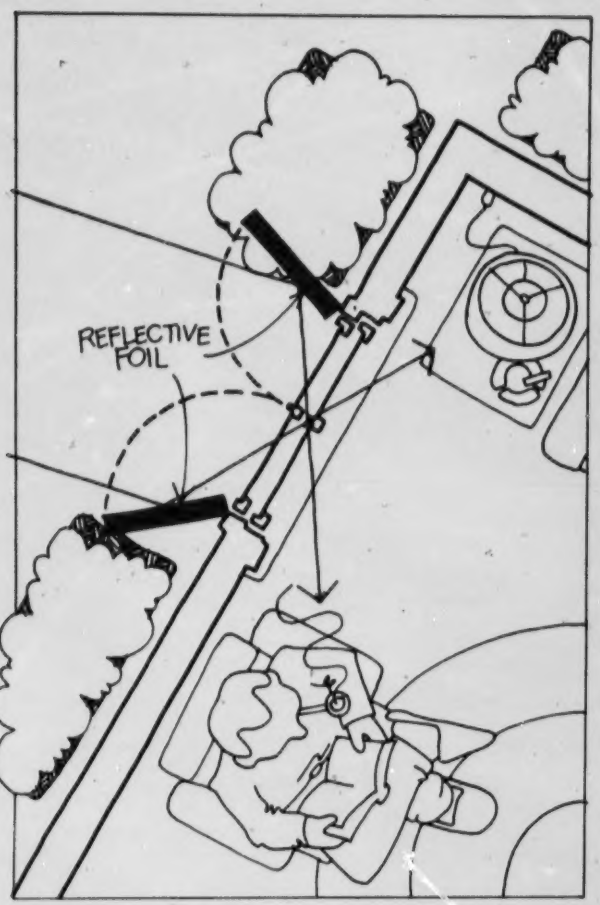
This shutter will be effective on any window. Whenever a window collects no solar heat and provides no light, it should be shuttered. Shaded windows should be shuttered — they never collect solar heat, they just lose it.

Advantages

- Exterior shutters do not have the condensation problems that sometimes plague interior shutters.
- This is a simple effective device which the average weekend carpenter can easily construct.

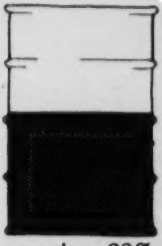
Disadvantages

- The worst part is having to operate the shutters — even during the coldest and snowiest days. Yet it is precisely on these days, when you don't want to go outside to close your shutters, that they do the most good and save you the most money.



- Exposure to the outdoors increases wear and tear on the materials, paint, and hardware.
- Ice can impair the shutters' operation.

Economics



Materials Costs: Materials can cost from $1.50 to $4.50 for each square foot of shutter. A 10 square foot shutter would thus cost from $15 to $45. Add up to $.25 per square foot for a reflecting surface.

Fuel Reduction: For each square foot of window surface covered each night with an outside insulating shutter, you should be able to save ⅛ to ¾ gallon of oil per season. A 10 square foot shutter will save 2-7½ gallons a year. If your shutter acts as a reflector as well, you can increase savings by as much as 20%.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 10-11.

Window Box

We can't say it often enough — the best solar collector is a simple window that you insulate at night. One way to gain more window area without adding a new one is to use a window box. A window box is a glazed plywood box that attaches to your windowsill. Sunlight hits and heats a blackened surface in the window box. Inside the box, the cool air is warmed when it touches the hot black surface. Warm air rises and flows naturally into the house. At the same time, cool air from the floor of the room is drawn into the window box where it is heated. While the sun shines, a window box provides extra heat for your house.

When building the window box, keep the existing window in place. The lower sash of the window acts as a damper. When the sash is up, heat is allowed in; when it is closed, it prevents heat from leaving the room. Be sure to stuff insulation in the gap between the upper and lower sashes so that cold air doesn't flow into your house along with the solar-heated air.

The absorbing surface of the box, either metal or plywood, should be painted black. Allow a two inch air space on both sides of the absorbing surface, and insulate the back and sides of the box. Use plastic or glass for the transparent cover — an old window sash works well.

Variations

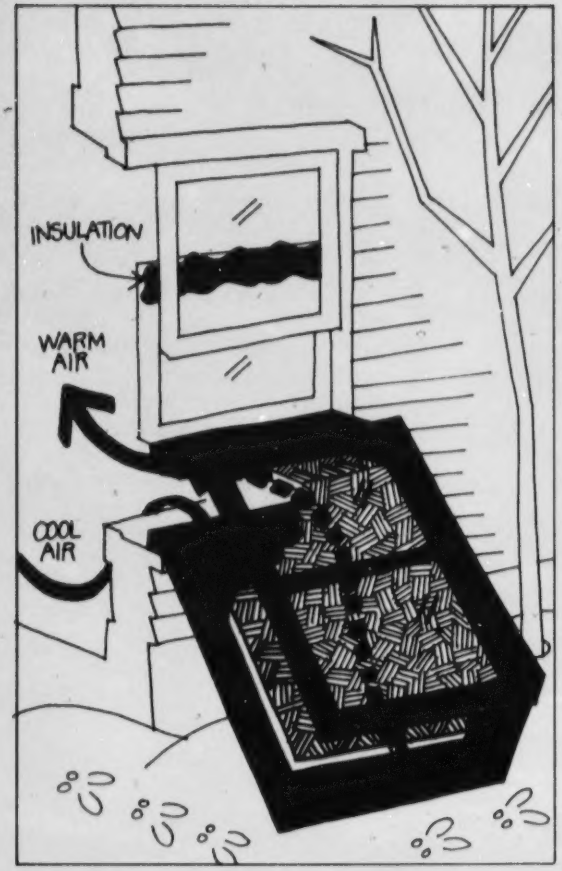
- You have many possible configurations to chose. You could connect two windows with one large box or have the window box for a second-story window act as an entrance canopy or shading device for the first floor.
- You can salvage many of the materials. Experiment with different designs until you develop the one that best suits you and your home.

Where This Works

This device is well suited for a house with small south-facing windows, where you cannot cut openings for new windows. It is easiest to install a window box on the first floor. An existing porch might support one at an upstairs window. If you plan to put on new siding, you can easily install a window box at the same time.

Advantages

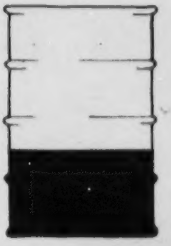
- The window box is one of the simplest devices you can build to collect solar energy. You can make it from inexpensive materials that you might have already.
- It has no expensive controls or mechanical parts.
- You increase the heat-absorbing area of your window without significantly altering it.
- The box can be moved and stored during the summer.



Disadvantages

- This device does not store heat for sunless time.
- You lose some heat as it is transferred from the window box into the house.
- The boxes may look unsightly next to your house.
- Unless you make an airtight seal between the box and your window, cold air leakage may cancel out the heat gain.

Economics



Materials Costs: The cost of the materials, including wood, insulation, glass or plastic, paint, etc., will range from $4.50 to $8 per square foot of window box area.

Fuel Reduction: Each square foot of your window box heater should save from ⅓ to ⅔ gallon of fuel oil each winter.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 7-8.

Greenhouses

Attach a greenhouse to the south wall and gather extra solar heat for your house while growing plants and vegetables. This unit surrounds a door and window, or several windows, and is supported by the wall of the house. The glass in the greenhouse collects heat from the sun and reduces the loss of heat from the house when the sun is not shining. To absorb heat, the greenhouse pictured has a dark gravel floor and a concrete door-step. If yours does not have a door-step you could add some heat-absorbing masonry or containers of water. Remember that as air warms it rises naturally! When the greenhouse gets too warm, a movable hinged top can be flipped up to ventilate it. You can open or close the door and window of the house to regulate the amount of heat entering the house from the greenhouse.

Make the frame from soft wood coated with preservative and cover it with glass. If glass is too expensive, use plastic such as polyethylene, although it has a shorter life span. Keep the amount of wood or other material in the frame to a minimum; too much blocks out the solar energy.

Be careful *not* to place your greenhouse where ice or snow falling off the roof can damage it.

Variations

- You can construct a smaller greenhouse that attaches to any window frame. One kind is the same size as the window, about 12 inches deep. It has two mesh shelves to allow the free flow of warmed air. A hinged top or movable center panel on the top provides ventilation.

Where This Works

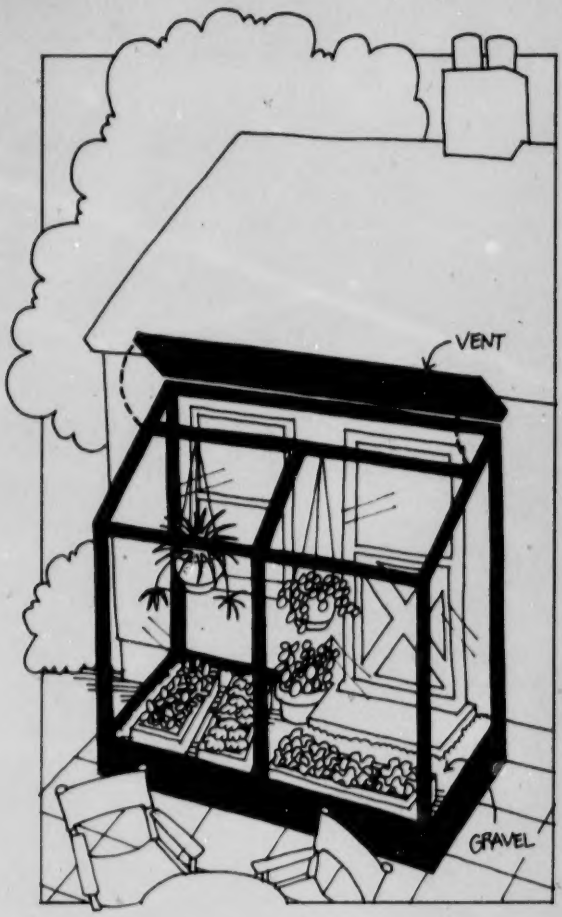
Almost any south-facing wall or window will work well. As indicated in the section, Solar Energy (page 5), windows that do not face directly south are also useful. Greenhouses facing east or west, can work if you mount reflectors on their north sides. Be sure there are no large buildings which shade your greenhouse in the wintertime when the sun is low on the horizon.

Advantages

- A greenhouse not only provides home heat, but the plants inside provide moisture during dry winter months.
- Larger greenhouses can also provide food. Any greenhouse will also allow an early start for garden seedlings.

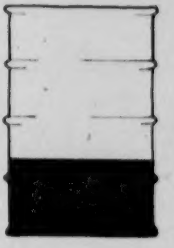
Disadvantages

- Some people do not want to spend 1 to 5 hours a week caring for plants.



- Units that abut ordinary wood-frame walls, may develop moisture build-up problems during the winter.
- On cold winter nights you may have to open the window and use home heat to warm the greenhouse to keep the plants from freezing.

Economics



Materials Costs: The materials to build this greenhouse should cost in the range of $3.50-$10 per square foot, depending on the quality and durability of materials used. A greenhouse for a 10 square foot window, for example, would cost between $35 and $100.

Fuel Reduction: Each heating season your greenhouse can save from ¼ to ½ gallon of fuel oil per square foot. For the above size window, savings would range from 2½-5 gallons per window per season.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 6-8.

Lean-To Collector With Storage

This uses a south-facing lean-to as a solar heat collector. This project differs from the others because it can store heat in rocks. The surface of the lean-to is painted flat-black to collect heat, and covered with glass or plastic. Rocks of the same size are placed in the lean-to to absorb and save heat for later use. Use about one cubic foot of rock per square foot of collector area. This is an air-heating collector — it uses air as the collecting and circulating medium. Air is warmed when it touches the hot black surface. A blower draws hot air from the collector down through the rock pile. Cooled air returns from the rocks, through concrete blocks turned on their ends, to the collector. When warm air is needed in the house, another fan draws air up through the warm rocks and into the house.

Make sure all ducts are air-tight. The rock-bin should also be air-tight, and its bottom, top and sides well insulated. The back of your solar absorbing surface should be well insulated so that heat stored in the rocks does not escape.

Include a vent when you design the lean-to. A vent allows excess heat to escape in the summer.

Variations

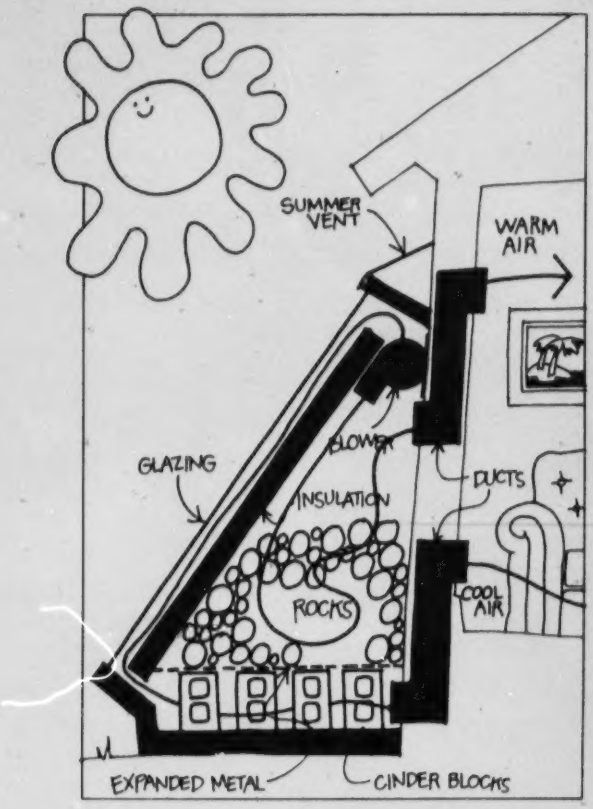
- This structure need not be mounted flat against a wall. It can be free standing and ducted to the room needing heat. There is also some leeway with the tilt. (See Solar Energy section page 5.) If you build a steeply pitched lean-to, place reflecting surfaces in front to increase the solar gain.

Where This Works

The most suitable place for a combined lean-to solar collector and rock storage system is on the south side of a house that has few windows. If you do not want or cannot have windows on this wall, this construction is particularly sensible. Also, if your house collects enough heat through its windows during a winter day, this lean-to can store extra heat for nighttime use.

Advantages

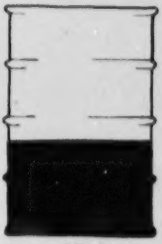
- This structure needs no major changes to the interior of the house. You only add two air ducts through the wall and a fan control switch.
- Because this structure is insulated and warm, it further insulates the existing wall against which it is placed.
- The storage bin allows you to save daytime heat for use when it is needed most — at night.
- As with many of these ideas, you may already have some of the construction materials on hand.



Disadvantages

- If your fan is too large, you will use excessive electricity, hence save little energy or money. It is important to use the proper fan size.
- In some cases you must build a foundation under the lean-to. This obviously adds to the cost.
- This device is considerably more complex than the other ideas mentioned, which increases cost and maintenance, while lowering cost-effectiveness.

Economics



Materials Costs: The materials to build your lean-to include plywood, paint, glass or other glazing, insulation, concrete blocks, rocks, ductwork, fan and miscellaneous vents, controls and finishes. The cost should run from $6.50 to $9 per square foot of collecting surface. This applies for a unit of medium size (100-200 square feet).

Fuel Reduction: With a medium size unit, 100 square feet of collector can save about 50-75 gallons of oil per heating season, or ½ to ¾ gallons per square foot.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 7-9.

Roof Trickle Collector*

If you have a south-sloping roof which needs repair, you can convert it into a trickle-type solar collector that uses water to gather solar heat for your home. Cover your roof with black-painted sheet metal such as corrugated aluminum. Allow water to trickle slowly over it to absorb its heat. Cover the assembly with glass or plastic. Collect the heated water at the bottom and drain it to a storage tank. Leave the tank uninsulated but place it in an insulated closet-like space. Blow house air through the closet. And voila — solar home heat!

A pump forces the water from the storage tank to the collector. A ½-¾ inch diameter pipe perforated with tiny holes is placed along the crest of the roof and squirts water down each of the troughs in the corrugated metal. The metal sheet can get very hot when water is not flowing over it. Make sure the sheet does not touch a part of your old roof that is unable to withstand high temperatures (like tarpaper or asphalt shingles).

Two cover sheets of glass or plastic are better than one, and will be more effective in cold weather. Make your collector air and water-tight and insure that it is self-draining when the sun is not shining. Otherwise, water will freeze and the pipes will burst.

Variations

- In some cases you can transform an existing aluminum or copper roof into a water trickle system.
- There are several other ways to move the heat from the storage tank to the house. The warm water can circulate through pipes buried in floors or ceilings. You can submerge the tank in a rock bin, and then blow air through the bin and into the house. The method you chose depends on your particular situation.

Where This Works

This project is most applicable to sunny south-facing roofs in need of repair. Part of the cost can be subtracted because the roof needs fixing anyway. Do not try this system on buildings with roof pitches lower than 40 degrees — the water will not trickle properly. Trickle systems work best on steeper pitched roofs.

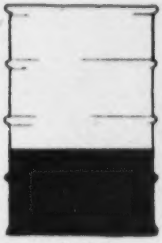
Advantages

- Because of the large areas of roof used for collection, this system can supply a large amount of your heat. It will reduce heat loss through your roof and provide double savings.
- It can be used all year round to pre-heat your domestic hot water.
- This is one of the simplest types of water-heating solar collectors you can make. The water-heat storage requires less space than rock storage.

Disadvantages

- The collector is less efficient than simpler ones described earlier. There is more chance for heat-loss, especially in the open water path where heat is lost through evaporation.
- The storage tank requires space in cellar or house — sometimes as much as a small room.
- The system is quite complex, requiring piping, a pump, a fan, and automatic controls to regulate the collector. These things can all break.

Economics



Materials Costs: The materials to build this collector and heat-storage unit, including sheet metal, glazing, piping, structure and water pump will cost about $4.50-$7.50 per square foot of collector area. This applies to systems in the 200-400 square foot range.

Fuel Reduction: Each square foot of this solar collector can be expected to save from 1/3-2/3 gallon of fuel oil each winter. For 100 square feet of collector at .50/gallon oil prices, yearly savings would range from $16-$33.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 7-8.

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*This concept was developed and patented by Dr. Harry Thomason. Construction plans of the system are available from Edmund Scientific Co., Barrington, New Jersey.

Solar Heating System Using A Conventional Hot Water Heater

If you are considering a small (200 square feet or less) addition to your house, this is an idea for heating that addition — using the sun. The system uses an oversized conventional hot water heater to store heat collected with solar collectors. The standard heating element provides back-up heat. The sun actually pre-heats the water and halves the amount of heat the conventional system must produce. Before trying this scheme, design the addition with maximum south-facing windows; face the roof toward the winter sun to provide a location for the solar collectors; insulate the building thoroughly.

This solar system requires a water-heating collector mounted to face the winter sun. Water is pumped through the collectors to a conventional, well insulated (add more than the unit comes with), hot water tank with an attached water-to-air heat exchanger coil. When heat is needed, air from the room is blown over these coils by a fan, warmed, and blown back into the room.

As a rule-of-thumb, use up to 100 square feet of solar collector for a 200 square foot addition. Provide up to 3 gallons of water storage for each square foot of solar collector. You can make the heat-exchanger out of standard ½ inch finned copper baseboard heating pipes.

Variations

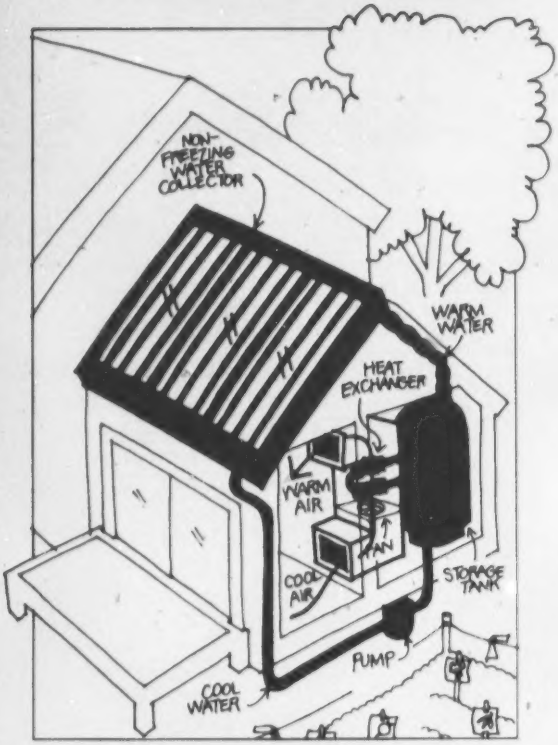
- Instead of an insulated tank, an uninsulated tank can be put in an insulated closet. When heat is required in the living spaces, open the closet doors and let the hot tank radiate heat into the room.
- Home heat is provided by hot water drawn from the storage tank and pumped through finned baseboard heaters in each room.

Where This Works

This works best in a well-insulated building which does not need to be kept very hot. The heat storage closet should be centrally placed to allow easy circulation of warm air. The system is appropriate only for small buildings, since the storage capacity of an 80 gallon domestic hot-water tank is small. You would need larger components for a space greater than 250 square feet.

Advantages

- This system uses readily available, familiar equipment. Since the system can use an existing hot water heater, the auxiliary heating element is already built in.
- Because heat is moved mechanically by pumps and blowers, you can locate systems components wherever you want them.

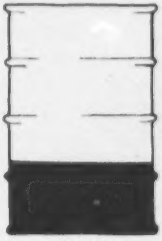


- Because the system is small, two or more units could heat different areas of the house.

Disadvantages

- This is an expensive way to use solar energy. It requires a water-circulating collector, pumps, heat-storage tanks, and electronic controls for the pump and fan, ducts and heat-exchangers.
- The storage tank and ductwork take up space. In a small building, this could be a problem.
- There is substantial heat-loss because the heat transfer from collector to room uses an indirect system.

Economics



Materials Costs: A system like this requires considerable plumbing supplies. You may have some on hand. Costs will probably range from $8 to $14 per square foot of collector or $800 to $1400 for a 100 square foot system.

Fuel Reduction: Because this system has storage, you can regulate and use the heat when you need it most. Savings can be figured at ½-1 gallon of oil per square foot per season or 50-100 gallons for a 100 square foot system.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 6-7.

Solar Water Heater And Garden Shed With Heat Storage

Build a storage shed in your backyard. Place a collector on the south-facing surface. Attach an insulated hot water tank horizontally about 18 inches above the top of the collector. A reflector above the collector surface increases the solar radiation on the collectors. Since the water storage is higher than the top of the collectors, the system can use thermosiphoning for water circulation.

Hot water is pumped to the house and used as needed. The back side of the structure is a garden shed with doors.

You will have to look elsewhere for the specific details of your water collector, but basically you will want to build a glazed box that contains a blackened, heat-conducting metal surface against which pipes (for best results use copper) are attached. Solar heat is absorbed by the black metal and transferred to the water in the pipes which then carries it to the storage tank or house.

You can make the collector in 8 foot long sections out of standard dimension building material. For this length collector your water storage tank should be 24 inches in diameter. Insulate the back of your collector assembly to prevent heat loss. Also, be sure to make provisions to avoid the freezing of pipes in the wintertime.

Variations

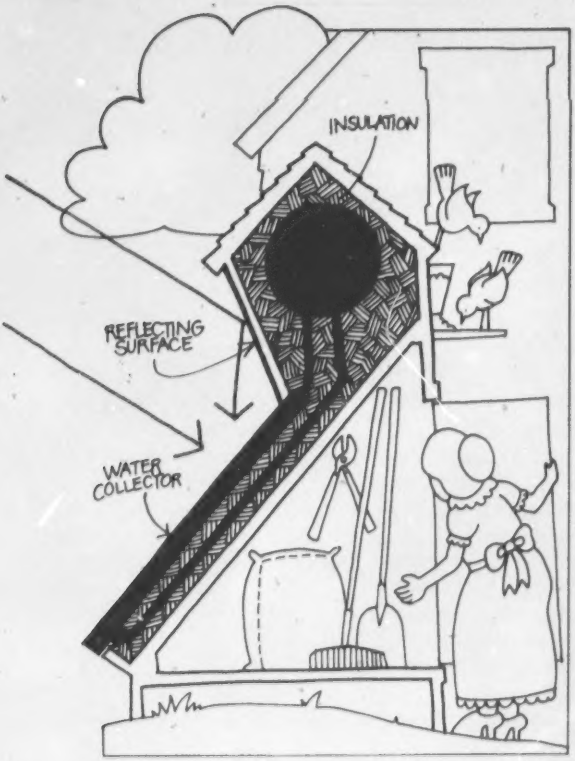
- You can easily change the size of the shed, both in height and length, as long as the proportions are kept about the same.
- Even after completion, additions can be easily made.
- To increase the collector's output, add a reflector on the ground in front of it.

Where This Works

Any free-standing device works best where the building to be heated receives too little sunlight. The existing heating system must also be considered. You can combine the device with a water-to-air heat-exchange coil to produce hot air for house heating. With greater difficulty and expense, you can combine the project with an existing hot water baseboard heating system. Most conventional heating systems use higher temperature water than this solar collector provides. Therefore, the baseboard system must be enlarged to compensate for the lower temperatures from the collector. Other options such as radiant panel heating are also possible.

Advantages

- Water is a very efficient heat-transfer and storage medium. As a result, collector, storage, and piping are all much more compact in a water system than in an air system.

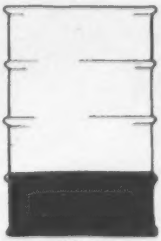


- By combining the collector with a shed, some of the costs of the solar system (structural framing and foundation costs) can be shared with shed costs.
- Thermosiphoning minimizes the mechanical complexity of the system.

Disadvantages

- This system needs protection against freezing. You can circulate an anti-freeze solution through the collector and then through a heat exchanger in the storage tank or you can drain the system on sub-zero nights.
- A separate collector loses more heat than one attached to the building.
- This system demands more skill in design and building than many of the previous, simpler ones. See the bibliography for help.

Economics



Materials Costs: The materials for 100 square feet of collector will cost $1,000-$1,600 or $10-$16 per square foot. This includes costs for the shed and the insulated pipe to the house, but no extra amount for new heating systems, if required.

Fuel Reduction: During each heating season, savings can be from ½-1 gallon of fuel oil per square foot of collector or 50-100 gallons for a 100 square foot model.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 5-6

Warm Air Collector Without Storage

This idea is for an air solar collector which cannot store heat for later use. Air-collectors work well in a free-standing structure where a liquid system might freeze. Here, cool room air is delivered through insulated ducts to the collector bottom. As it rises over the collecting surface the air warms and then returns to your house through another insulated duct at the top of the collector. Thus, when the sun shines, you collect extra heat for your house. When the sun stops shining, close a vent to your collector, otherwise the warm air in your house will flow outside.

You usually need a fan to blow the air through the collector and back to the house. Sometimes however, the air will rise naturally by *thermosiphoning*. The fan should blow 2-3 cubic feet of air per minute per square foot of glass in the collector.

Constructing your own air solar collector is tricky, but you can learn how! Check the appendix for sources of further information.

Variations

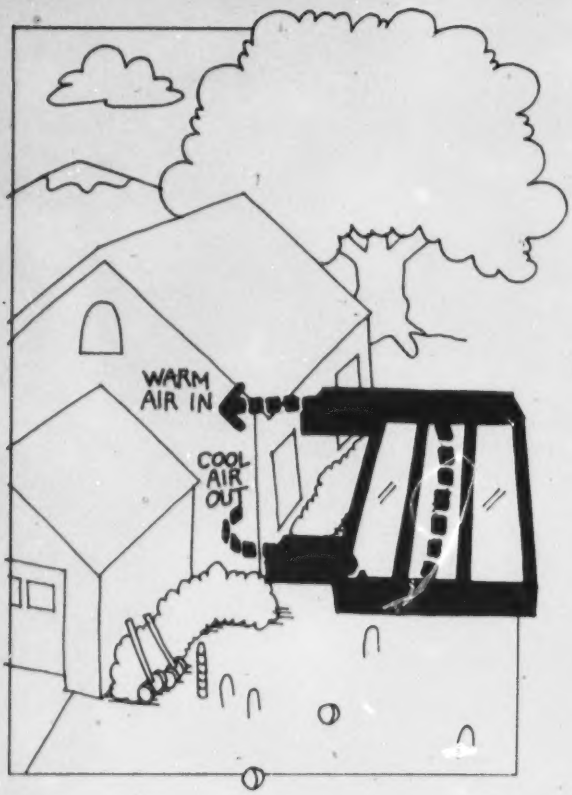
- Enhance your collector's appearance by combining the warm and cool air ducts in one structure and running them underground.
- Your collector will look and work better if you attach it directly onto another structure such as a porch, a storage area. This also cuts the collector cost — only part of the money is for the collector.
- Place a large reflector on the ground next to your unit to greatly increase the heat output.

Where This Works

In densely populated areas or in residences that share walls with other buildings, a free-standing collector is often the only solar device that can be used. If you can place the solar collector about two feet lower than the rooms you plan to heat, you can take advantage of thermosiphoning — heat's natural flow — and reduce the need for a fan.

Advantages

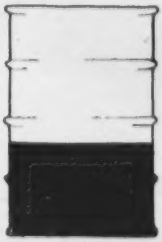
- Because this collector is free-standing, it can be given ideal orientation and optimal tilt. (See Site-Conditions section.)
- A separate collector does not appreciably alter the structure or appearance of the building.
- You can easily detach the unit during the summertime to avoid overheating.



Disadvantages

- For the energy provided, a free-standing collector is often more expensive than an integral or attached one. The support structure and the ductwork from the collector to the house add the most cost.
- Ducts can lose heat. You should insulate them with the equivalent of at least 6 inches of fiberglass insulation.
- In densely populated areas, you may face the problem of establishing "sun rights," the right to unobstructed sunshine.

Economics



Materials Costs: The materials, such as glass or plastic, wood, paint, absorbing surface and ductwork, for a solar collector and structure of 100 square feet might cost from $450-$750 or $4.50-$7.50 per square foot. This figure can vary substantially with the quality of the collector.

Fuel Reduction: With this medium-size unit, you can expect savings of ⅓-¾ gallon of fuel oil for each square foot of collector or 33-75 gallons for the entire unit.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 7-9.

Garage

A new building simplifies your task of "going solar." It is far easier to design and build with solar from the start. Even if the new building, like a garage, does not need heat, it can provide space for the collectors and heat storage. The new structure should be next to the rooms requiring heat to simplify heat circulation. Make sure the old building does not shadow the new one at any time. The storage area, even when heavily insulated, loses some heat. So whenever possible, it is more efficient to place the storage in the house. Then the lost heat is not wasted — it is "lost" to the living spaces which need it anyway.

If you use an air solar collector, you will store heat in a rock bin. The rocks should be uniform in size with diameters of 1½-2½ inches.

Solar heated air from the collector should feed directly to an air space at the top of the rock bin. To retrieve the heat, draw it from the top of your storage bin. The air should move in a direction opposite to the one in which it was delivered.

Other schemes are outlined below, but this is a project for which most people will need more information than can be given here.

Variations

- There are endless ways to use new structures as partial solar collectors. A new barn, trash shed, billboard or picnic shed can easily become a solar collector. At the same time there are almost as many places where your heat storage can go. One well-known solar pioneer placed 16 foot-high rock storage tubes in the entrance foyer of his house. Use your imagination!

Where This Works

A variety of places are suitable. The main point is that solar collection can be integrated with a new building, and greatly reduce the cost of the solar system.

Any of the other schemes in this pamphlet can be applied to a new building; this one is unique because a new structure supplies heat for the existing building.

This idea is particularly suitable, if, by adding a new structure, you can achieve a better solar orientation.

Advantages

- In many cases, an unheated attached structure will help reduce heat loss from the existing building.
- When building from scratch, it is much easier to integrate solar heating with the design. An existing building is not often ideally suited for solar use. In a new building, you can make sure that everything works from the start.
- A good collector and storage system is the most efficient way to store for more than one day.

Disadvantages

- This project requires engineering skills that are often beyond the grasp of many homeowners. Do not be too discouraged; the more you work with it, the better you will get!
- This project also carries a high price tag. If you cannot foot the entire bill now, design with solar in mind and install the system later.
- The high cost of this system makes it less cost-effective than simpler ones.

Economics

Materials Costs: It is almost impossible to estimate the cost of an undefined system. However, it would certainly be one of the most expensive. A good guess is between $8 and $14 per square foot for materials.

Fuel Reduction: A well-made collector and storage system could save ½-1 gallon of fuel oil per square foot each heating season.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 6-7.

Glassed-In Porch

Another form of new construction that can save fuel is a glassed-in south porch. Like a greenhouse, a glassed-in porch traps heat while the sun shines. Solar heated air in the porch enters the house through an existing window or a new duct opening that you can close at night. You can improve the effectiveness of the porch by adding thermal mass (see page 14) and using insulating shutters at night.

Every time you open a door you lose heat and money. If you design a porch as a new entrance, an air lock in a sense, it will act as a buffer zone between indoors and out. It saves fuel by allowing the less-expensive sun-heated porch air to escape from the open door, rather than the expensively-heated indoor air.

Variations

- If you cannot afford to cover the full area of your porch with glass, use a plastic such as polyethylene instead. However, it will not be as attractive or last as long as glass.
- You can transform an existing open porch into an enclosed porch.

Where This Works

When you need more living space a sunny glass porch can be a great solution. Porches on the north side of your home will not act as a solar collector but can minimize heat loss by acting as a buffer between the house and the cold outside.

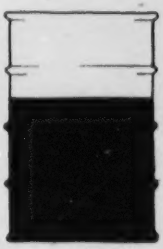
Advantages

- If you plan to build the new living space anyway, you achieve great energy savings for very little money with this project. Remember, however, this glassed-in porch gets very warm on sunny days and very cool on cold nights if there is no other heating system.
- A porch can make exciting changes in the way your house looks and functions.

Disadvantages

- The porch primarily heats just adjacent rooms. If a distant room needs heat, additional ducting, and possibly a fan, becomes necessary. This means more cost and complications.
- If there is no place to store excess heat, the porch can easily overheat and become uncomfortable.
- The porch may steal sunshine from rooms that formerly were well-lit.

Economics



Materials Costs: The design of porches vary so much that it is difficult to give estimates here, though $.50 to $4. might be an approximate range. Your building contractor can help.

Fuel Reduction: You save as much from reduced infiltration and the porch's insulating role as you do from solar gain through the windows. As a rough guide, though, you can figure a fuel savings of ¼-½ gallon of oil per square foot of south glass for a heating season.

Cost-effectiveness: On a 1-20 scale, this suggestion earns a rating of 9-16.

Solar Hot Water Heaters

Introduction

Up to this point we have discussed home heating and energy conservation. But there is another important area to cover — domestic hot water. Fully 20% of the energy used in our homes heats our water for washing and bathing. The sun can help supply that energy.

However, before discussing water heating, we should look at ways to cut down what we use. In a typical household in the United States, each person uses roughly 20 gallons of hot water per day. This is dramatically higher than in most of the world. You can cut down tremendously without sacrificing at all. It also greatly saves energy — and money.

You can reduce water use in a number of ways. About 50% of the hot water we use is for bathing, about 25% is for laundry and the rest is for cooking, lavatory and miscellaneous cleaning. A shower uses far less water than a bath. You save even more with a water-conserving shower head that gives off a spray of water rather than a hard steady stream. If you cut back hot water used for bathing by 50%, you cut your water heating bill by 25%. You can save on laundry hot water by only washing full loads and using cooler water temperatures. Even the kitchen has quick remedies — rinse dishes in a basin of hot water rather than under a steady stream of tap water. Once you cut your hot water use as much as possible, then you can look for cheaper ways to provide what hot water you really do need.

Your present hot water heater draws water from a well or water main at temperatures around 50 degrees F. Its task is to warm that water to 125 degrees F or more, and then store enough of that water so you don't run low too quickly. Solar water heating is very simple — a garden hose sitting in the sun is perhaps the simplest example of a solar water heater. There are obviously more efficient heater designs possible, but they are only improvements on the basic scheme. What complicates solar heated water systems, is the need for storage, the desire to shower at night or on a cloudy day.

A simple system without storage is very inexpensive and easy to make, but does not provide hot water (i.e., no showers) at night or during inclement weather. More complicated systems are needed for continuous hot water supplies. An unfailing supply of hot water requires an auxiliary hot water heater. Nevertheless, solar water heaters are practical and a good first solar project. Moreover, the technology is readily available today; solar water heaters have been used for over 20 years in Florida, Israel, Japan and Australia. In addition, a water heater is not as big an undertaking as a house heating system. Making your own solar water heater is a good way to gain personal experience with solar heating before moving on to bigger projects.

In addition, solar hot water heaters have another important economic advantage. While solar house heaters sit idle during the warm months, solar water heaters are needed year-round. They save you money every time the sun is shining. And, as we've seen, water heating is a large part of your total energy bill.

Solar hot water heating collectors are similar to other collectors in most respects. The major construction difference, besides their smaller size, is that hot water heaters, because they operate all year-round, should be tilted to make good use of both winter and summer sun. For lat. 40°N area, tilt these collectors about 40 degrees from horizontal.

The biggest technical problem, common to all solar hot water heaters in northern climates, is the danger of freezing in the pipes and water channels. We present three types of heaters here, from simple to complex. The simplest avoids the freezing problem entirely. It is drained and empty all the time except on sunny days or when it's closed up tight and full of hot water. The second system, the type most common world-wide, has been modified by the addition of a heat exchanger and anti-freeze so that the liquid in the collector can't freeze. The third system can either use the same solution, or be designed to drain when the pump is off. Thus, the more complex the system, the more complex the freeze control mechanism.

The other big problem with a water heater is corrosion of the components. Our simplest system uses conventional plumbing and a plastic collector. The other two would probably require copper in the collector and piping. Other metals such as aluminum and iron can be used, but you would need corrosion inhibitors which you do not want in your drinking water. Numerous minor problems can arise. Before you start to build your water heater, read the references listed in the bibliography.

The main point here is that you *can* build a solar hot water heater; it *can* be simple and cheap, and it's worth doing. You'll save money and learn a lot.

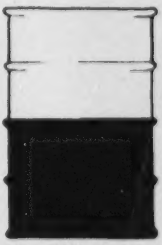
Trough Type

The simplest solar water heater is a trough of water sitting quietly in the sun, soaking up heat. Fill the trough in the morning, use hot water in the afternoon. The water stays hot for several hours. If you want to store hot water overnight, drain the trough to an insulated tank or make sure that there is enough insulation over and around the tank. (Six inches isn't too much.)

You can improve the basic trough by adding a transparent cover and plumbing for filling and draining. The trough in the illustration rests in an insulated box with a roof over it. Both slopes of the roof are insulated and have reflecting surfaces on the inside. One side has a layer of glass under it; it opens and closes like a shutter to let the sun in through the glass. It is held in position by adjustable struts so it can tilt to reflect summer and winter sun. Mount your unit on the roof like this one, or on a tall support structure so that hot water can *gravity-feed* to your sink or shower.

The unit will heat about 1 gallon of water per square foot of glass on a sunny day. For a family of four the trough should be about 60 square feet or 6 feet by 10 feet, with water four inches deep. Average hot water consumption in the U.S. is 20 gallons per person per day. If you're conservative you can use the more reasonable amount of 10 gallons a day.

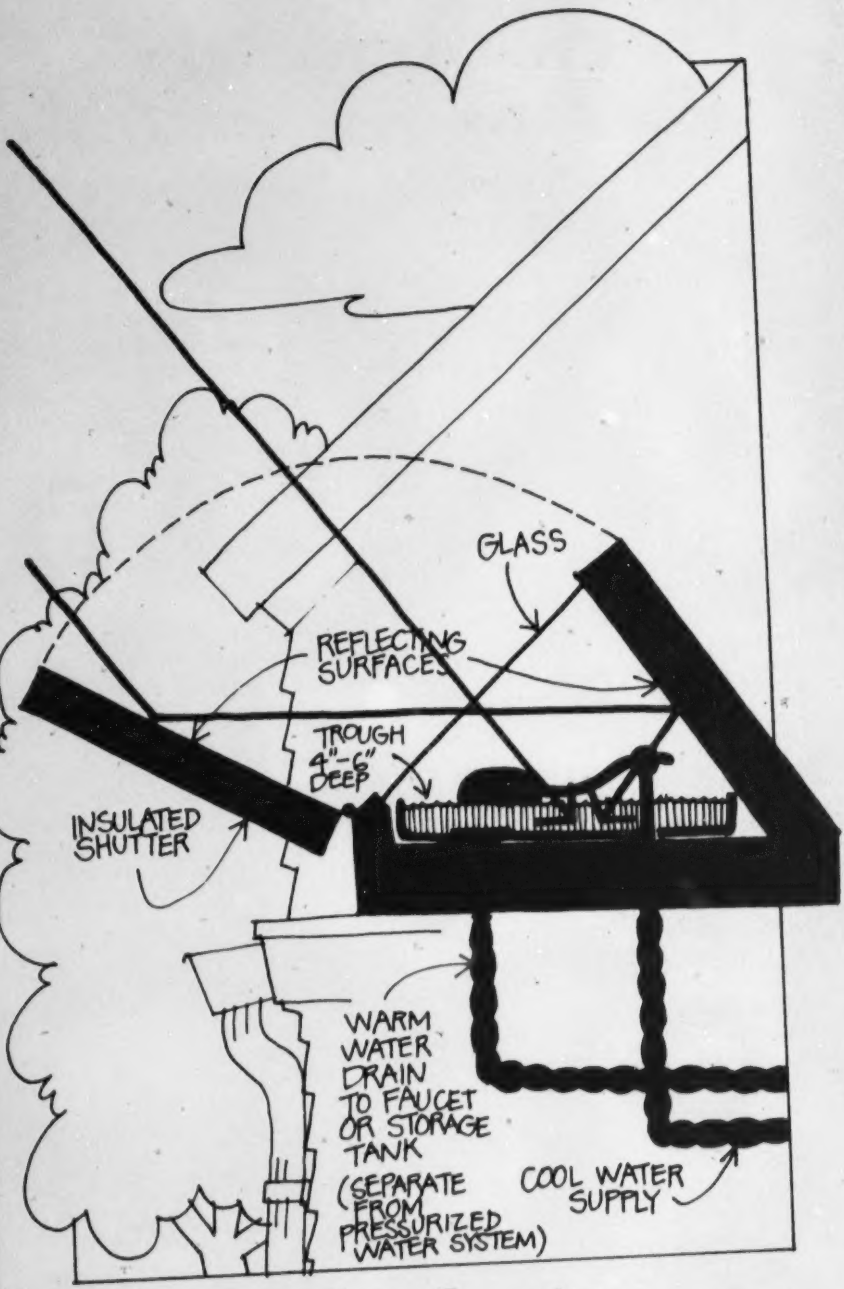
Economics



Materials Costs: You can build a small simple unit from materials on-hand, or inexpensive store-bought parts. Start out simply and improve it as you go. Costs will range from $5-$10 per square foot.

Fuel Reduction: This water heater is not particularly efficient but because it operates year-round, the savings add up. You can figure savings of ¾-1 gallon of oil per square foot of collector per year or, since many water heaters are electric, 22-30 kwh per square foot per year.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 9-11.


GLASS
REFLECTING SURFACES
TROUGH 4"-6" DEEP
INSULATED SHUTTER
WARM WATER DRAIN TO FAUCET OR STORAGE TANK
(SEPARATE FROM PRESSURIZED WATER SYSTEM)
COOL WATER SUPPLY

Thermosiphoning Collector

This is a more expensive solar hot water heater than the trough type, but it is also more efficient; it heats more water, hotter, per square foot and stores it longer. You can use any of several conventional water heater collectors. The easiest for you to build would probably be ½ inch copper tubes soldered 6 inches *o.c. (on center)* to a thin copper sheet which is painted black, and mounted in an insulated box with two layers of glass on top. The storage tank is mounted right above the collector to minimize piping. The water circulates by thermosiphoning, or natural circulation. No pump is needed. Warm liquid from the collector rises and cooler liquid from the tank settles down in a slow, continuous flow from collector to tank to collector. To facilitate this flow, use large piping (¾ inch-1 inch diameter) between collector and tank; keep the number of bends and elbows to a minimum, and mount the tank 2 feet higher than the top of the collector to prevent reverse flow at night. To prevent freezing, use the non-freeze system illustrated. Here, the fluid circulating in the collector is anti-freeze. Instead of flowing directly into the tank, the fluid moves through a heat exchanger which transfers heat to the water in the tank. It is highly recommended that you use a non-toxic anti-freeze such as propylene glycol in case a leak develops.

Insulate the tank well (8-10 inches) to minimize heat loss. Because the tank must be above the collector, it often ends up on the roof — make sure your building can support its weight. You can change the appearance of the tank enclosure by disguising it as a chimney.

If you decide to make one of these systems, read one of the referenced publications listed in the bibliography before starting.

Auxiliary Heating Arrangement

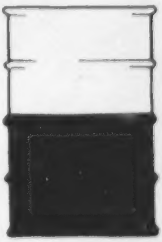
See "Pumped Water System," page 50.

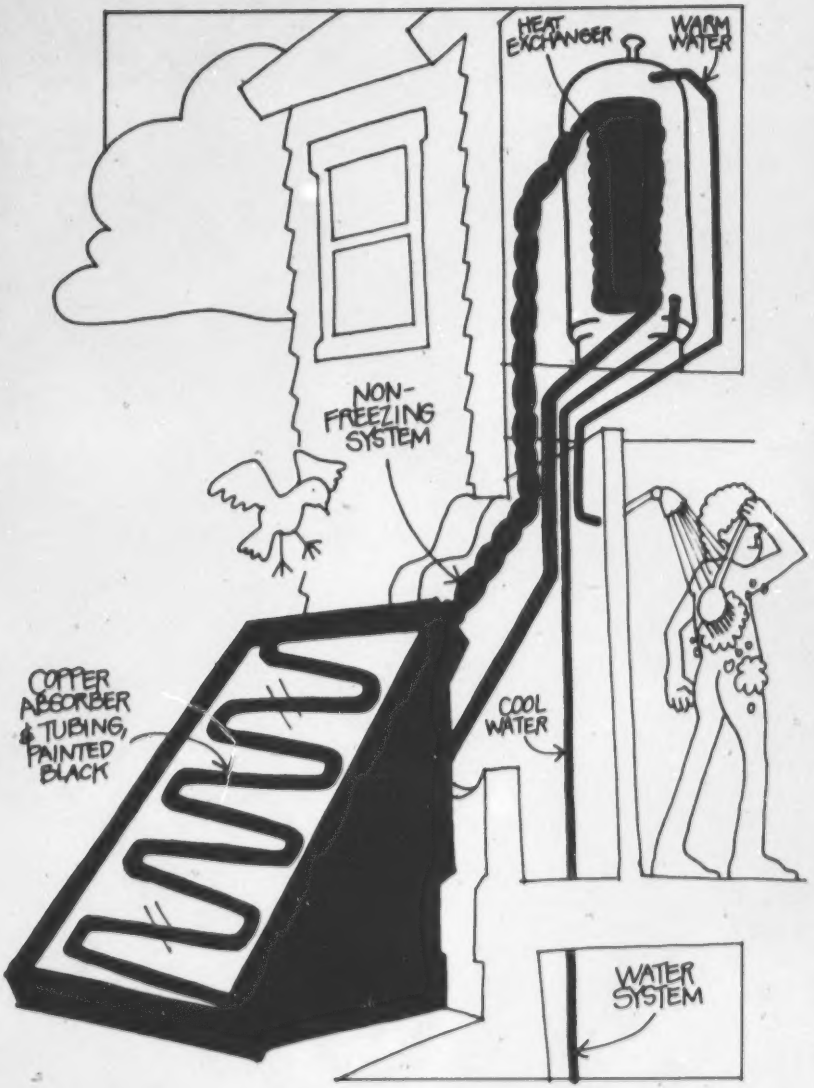
Economics

Materials Costs: There are many ways to make one of these heaters. Average costs are from $10-$16 per square foot.

Fuel Reduction: A well-made unit, with 15-20 square feet of collector per person in the house will save from 1½-1¾ gallons of oil per square foot per year, or 45-52 kwh per square foot per year electricity.

Cost-effectiveness: On the 1-20 scale, this suggestion earns a rating of 9-11.




HEAT EXCHANGER
WARM WATER
NON-FREEZING SYSTEM
COPPER ABSORBER & TUBING, PAINTED BLACK
COOL WATER
WATER SYSTEM

53

Pumped Water System

This system is more efficient and much more flexible in layout than the thermosiphoning collector. Rather than natural heat flow, the system uses a small pump to circulate water through the collector when the sun is out. This allows you to place the storage tank anywhere in the house, and use ½-inch piping throughout. The pump moves less than 50 gallons per hour, so cost and power consumption are low.

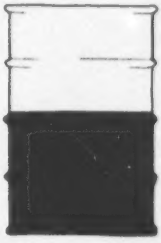
Prevent freezing by using a non-freeze system (like the thermosiphoning collector) or design a mechanism for draining water out of the collector. The collector is similar to that used in the thermosiphoning design. Again, allow 15-20 square feet of collector per person.

Auxiliary Heating Arrangement

This arrangement works for either a pumped-water or thermosiphoning system. If you want a constant supply of hot water, treat the collector as a pre-heater for your conventional water heater. The conventional heater will act as an auxiliary, and turn on only when needed, usually on cloudy days.

Two tanks are used in the best arrangement, with the solar storage tank serving as a pre-heat supply tank for the conventional hot water heater. The size of the tank depends on the size of your family. Allow 10-20 gallons per person.

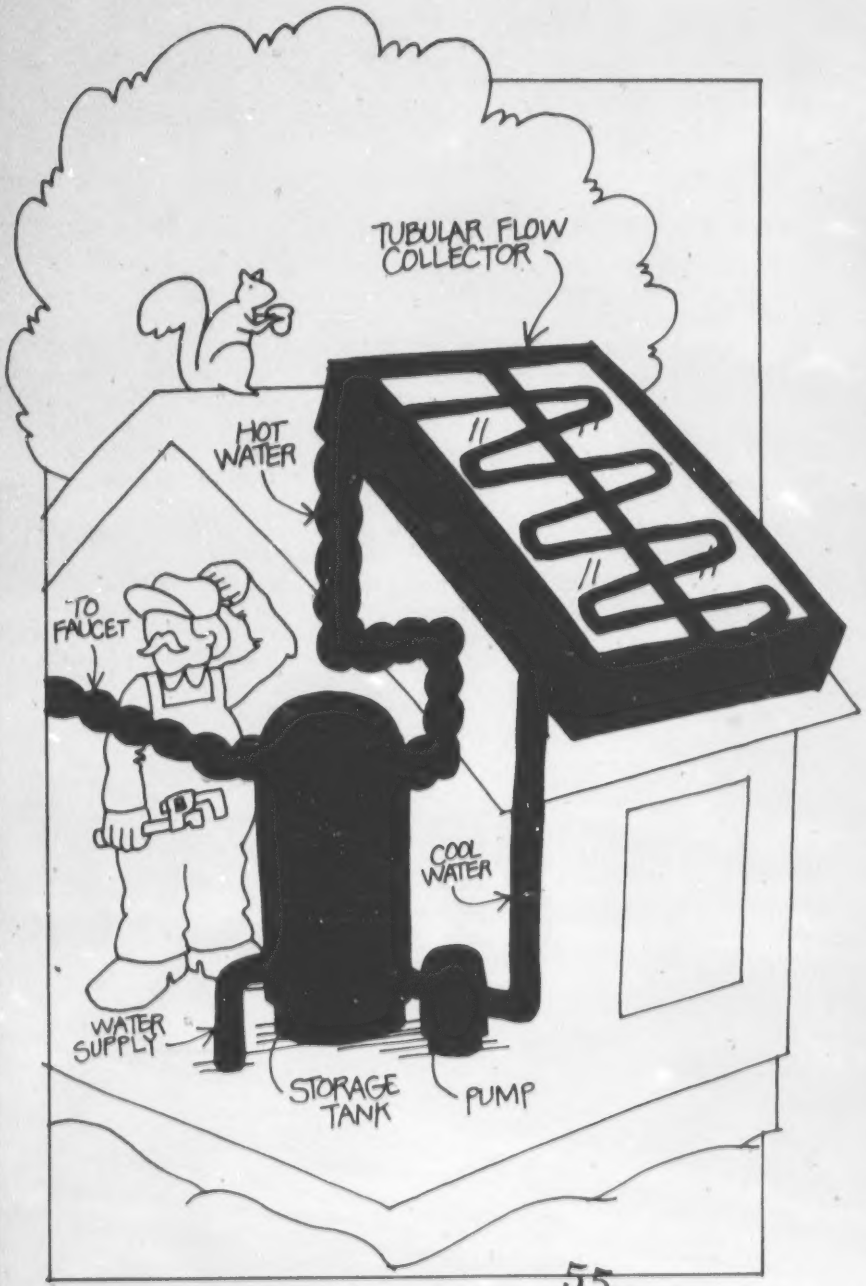
Economics



Materials Costs: This system is slightly more expensive than the thermosiphoning one. The cost difference is for the pump, a control device, and some additional plumbing. Figure $10-$16 per square foot of collector.

Fuel Reduction: A good unit can save from 1½-2 gallons of oil per square foot per year, or 45-60 kwh per square foot per year.

Cost-effectiveness: On our scale of 1-20, this suggestion earns a rating of 10-11.


TUBULAR FLOW COLLECTOR
HOT WATER
TO FAUCET
COOL WATER
WATER SUPPLY
STORAGE TANK
PUMP

55

Choosing A System:

Examples Of The Ideas Applied To Six Houses

In deciding which solar system to put in your house, use two important criteria — the cost-effectiveness rating and the appropriateness of the scheme for you and your house. To test for the latter, study your house with the following points in mind: What is the construction of the house? What is its orientation? How are the windows? Does the house already overheat with its windows or does it never get any sun? How can you combine the solar heating system with the existing heating and distribution systems? Is there space available on the roof, the walls or out in the yard? How complicated would it be to alter the existing structure? Is the angle of the roof slope small, and appropriate for year-round domestic hot-water heating, or is it steep and most appropriate for winter house-heating? Structurally, can thermal mass be added to the house or should it be separate? The following examples show how some of our ideas might be applied and adapted to six representative houses. Often several ideas can be effectively applied at the same time.

The ideas in this kit are presented in an appropriate progression from the simplest to the most complex. Cost-effectiveness often reflects this progression. Go down the list of ideas, take each design and evaluate how well it applies to your house. This kit was designed for you — to offer adaptable ideas that you can modify to fit your own special needs and unique situation.

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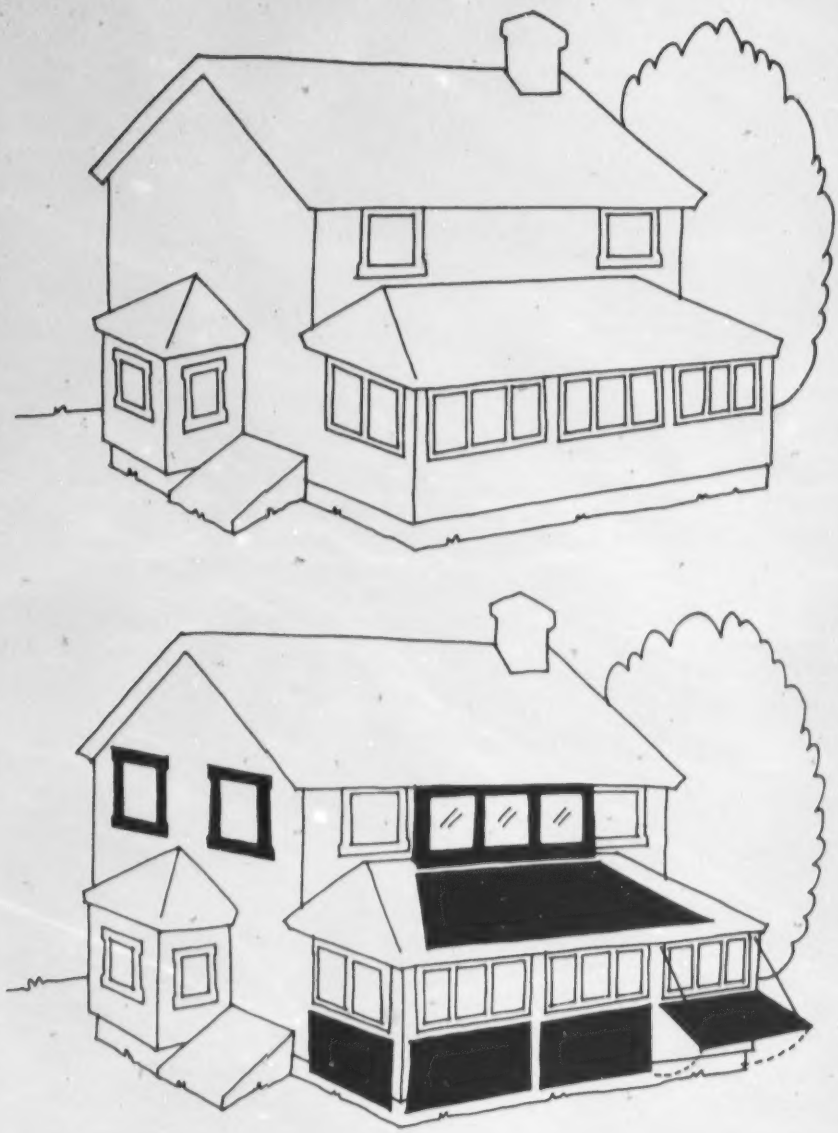
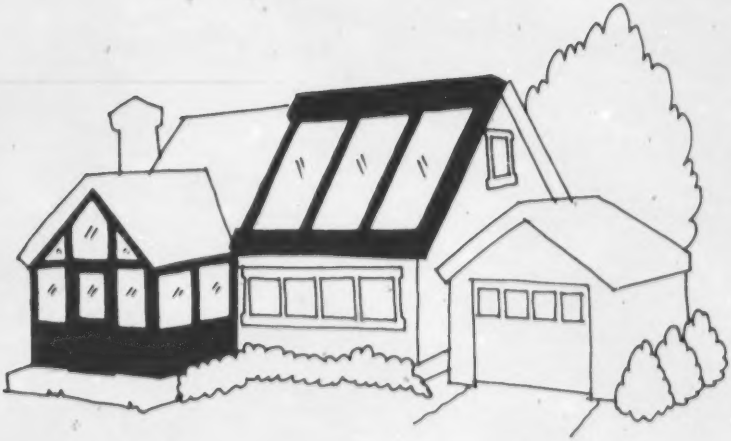
A large **window box** joins three south-facing windows. The **outside-mounted insulating shutters** can be used to reflect sunlight into the west-facing windows. Both ideas effectively increase the amount of solar energy entering each window. In summer the window box could be removed so windows could be opened.

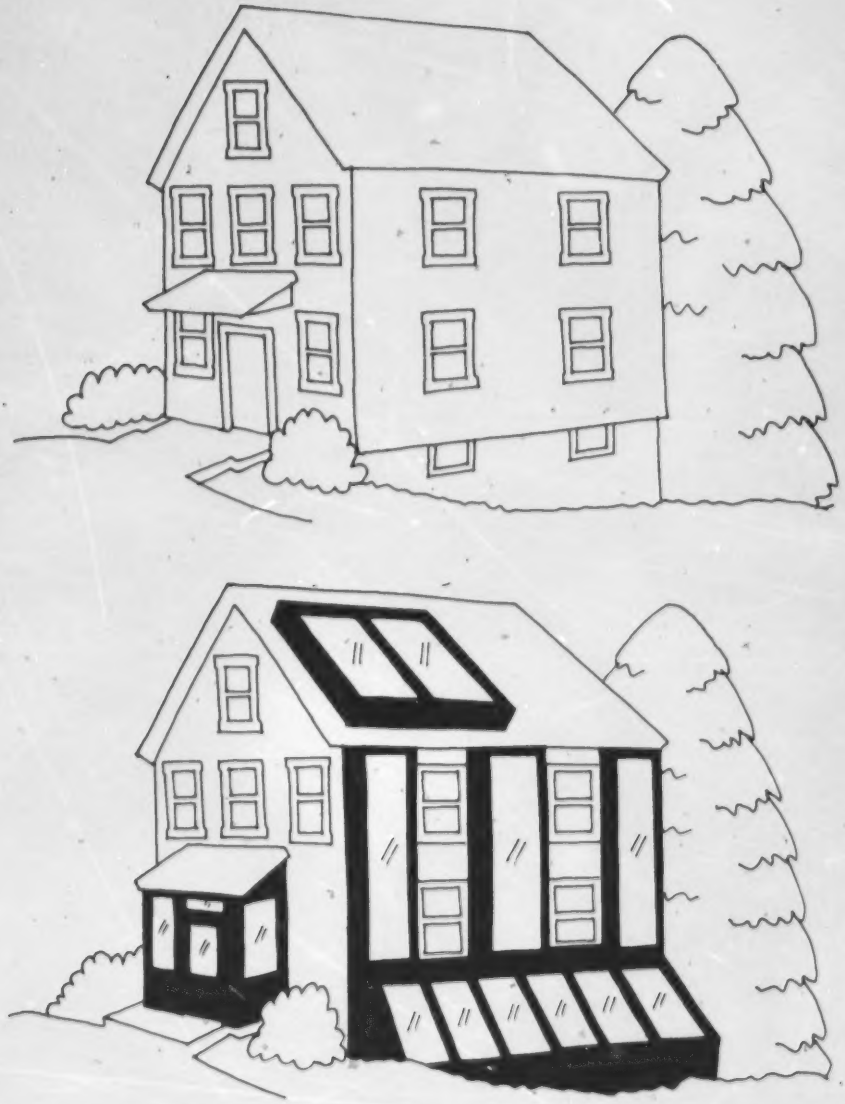


This house is off to a good start with its large glassed-in porch. **Outside-mounted insulating shutters,** with reflective foil faces, would increase the daily solar input to the porch. At night they would be closed to hold the heat in. The slope of the porch roof could also be an effective reflector for a **wall-mounted solar collector**. Also added are a **domestic hot water collector** and more windows.

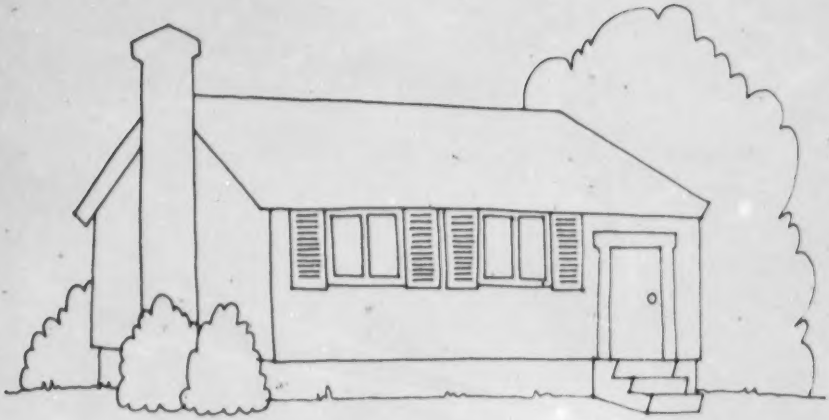
58

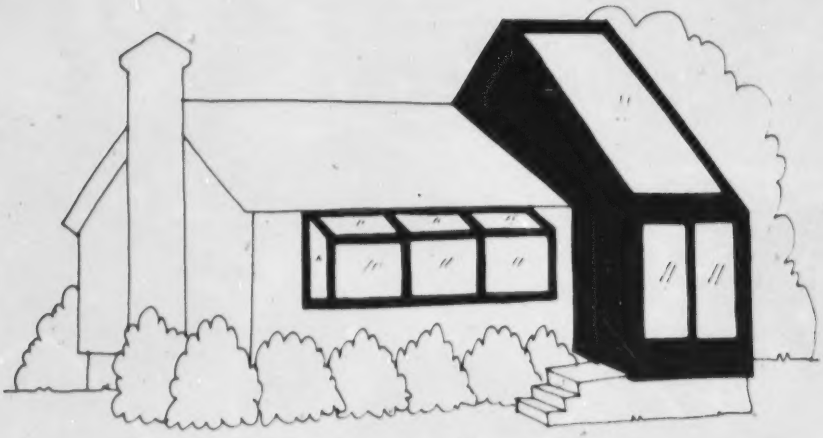


This house is a natural for solar energy with its big south-sloping roof and large south windows. It would be even more appropriate for solar application if that roof were a leaky slate roof in need of repair. It could then be **converted into a collector.** If air ducts could not be run easily between the roof and basement storage, a liquid system might then be appropriate. The entrance porch offers the possibility of simple conversion to a **glassed-in porch.**



With both yard space and wall space available for solar collection, a **lean-to collector with rock storage** could be used across the entire south face of the building. If the building is masonry, it could be partially converted into **vertical wall mounted collectors** between the windows. The roof angle is good for a **pumped domestic hot water heater** and the porch could be enclosed for an **entry foyer.**





Greenhouse frames around each south-facing window, a new **entry foyer** and **solar domestic hot water structure** could be added to this house. Also, additional shrubbery acts as insulation.

In the view of a typical city street comprised of town houses there is a wide variety of possible alterations. It is not necessary that all the homes use solutions that look the same. Each family's needs and budget would determine the solar application most appropriate for that family.

Glossary

baseboard heating — space heat provided by natural convection off base-board heaters (electric or hot water).

British thermal unit, or Btu — the quantity of heat needed to raise the temperature of 1 pound of water to 1°F.

cellulose — the kind of cellulose used in construction for insulation is made from reprocessed paper and other wood by-products.

electrical resistance heating — a type of space or water heat. A wire or coil heats up when electricity flows through it; the wire or coil then heats the air or water.

fiberglass — this insulating material is available in flexible batts and rigid boards and is usually made from a mineral base.

heat exchanger — a device (like a coiled copper tube) which is immersed in a tank of water transfers heat from one fluid to another (or to a gas like air), through an intermediary metal surface. A car radiator is one example of a heat exchanger.

heat pump — this is a device which has the ability to take heat from a cold place, thereby making that place colder, and transferring that heat to a warm place, making that place warmer. This is a means of warming a house. This process can be reversed for cooling.

insolation — the amount of solar radiation — direct, diffuse and reflected — striking a surface exposed to the sky.

polyethylene — a low-cost plastic, sold in sheets or films, which is used as waterproofing in construction.

polyurethane foam — this very light, insulating material can be bought in rigid boards or blocks. A chemical type of polyurethane can be "foamed" in place by a professional installer.

radiant panel heating — these panels have *integral* passages for the flow of warm air or liquid. Electricity or hot water heats a large surface — the heat is then transferred to the room by thermal radiation.

retrofit — a "shop" term for re-fitting an existing building with solar heating or cooling.

thermal mass/thermal lag — different housing materials store heat for varying lengths of time. Heavy materials like concrete, masonry and water provide thermal mass for a house — they store heat and allow the house to remain in a comfortable temperature range while the temperature outside fluctuates.

thermosiphoning — the natural movement of heat in fluids. Cool fluids are denser (than warm fluids), they sink due to gravity. Warm fluids are lighter, they rise and carry heat upwards.

tube-in-plate absorber — in this aluminum or copper absorber panel, the heat transfer fluid flows through passages in the plate itself.

ureaformaldehyde — another kind of foamed-in-place insulation similar to polyurethane foam (see polyurethane), but with different structural, chemical and combustion properties.

Velcro® — a trademark name for a fastening material used by the clothing industry.

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Alternative Sources of Energy. Route 2, Box 90A, Milaca, MN 56353.

Solar Age. SolarVision, Inc., Church Hill, Harrisville, NH 03450.

FOR INFORMATION ON SOLAR ENERGY SOCIETIES CONTACT:

The American Section of ISES
American Technological University
P.O. Box 1416
Killeen, Texas 76541

For further reading we recommend the following titles:

The Solar Home Book
by Bruce Anderson/Michael Riordan (Cheshire Books) 1977

The fundamentals, history and technology of the solar home in non-technical language. Over 160 illustrations. Includes climatic and design data plus sources for information and supplies. *"Best book yet on solar"* — N.Y. TIMES.
304 pages, Soft Cover $8.50

Solar Energy Home Design in Four Climates
by TEA Staff (edited by Charles Michal) 1975

Based on work for AIA Research Corp. Designs for four solar homes, stressing air heating systems; explains engineering and design methods used. Many drawings, charts, tables; more than 100 sources for components.
200 pages, Soft Cover $12.75

Solar Energy and Shelter Design
by Bruce Anderson (TEA, Inc.) 1973

Layman's look at basic elements underlying use of solar energy. Non-technical treatment discusses ways to collect, store, use and conserve. Useful tables, charts, bibliography. Text at several colleges.
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Solar Energy: Fundamentals in Building Design
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Complete guide for the professional. How to achieve optimum energy-efficient design. Cost-efficient ways to use solar energy for heating, cooling, hot water. Stress on low-impact technology. Profusely illustrated.
350 pages, Hard Bound $21.50

The Solar Age Catalog, 1977
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Cram-packed guide to solar product manufacturers and services, with contributions by foremost authorities. Most comprehensive solar directory ever published. Complete dossier on current state of the art.
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Solar energy for heating homes need not be as complex and expensive as some people suggest. The Fuel Savers was originally prepared for the Northwest New Jersey Community Action Program Agency (NORWESCAP) under the auspices of the U. S. Community Services Administration as part of their program to weatherize low-income people's houses. It attempts to "demystify" how solar energy works and to stimulate the reader's creativity through numerous ideas that can be accomplished with simple, ordinary tools and materials.

Construction plans for many of the ideas discussed in this book are being developed. Contact Total Environmental Action, Inc. for more information.

Total Environmental Action, Inc. is a research, design and education firm, placing special emphasis on energy use in buildings. Based in Harrisville, New Hampshire, TEA's goal is to improve the quality of people's lives through the creation of satisfying, ecologically sound environments. **The Fuel Savers** is based on years of both organized research in energy conservation and solar energy, as well as involvement with dozens of building projects as designers, architects, engineers, and consultants. It attempts to provide important information to large numbers of people who might not ordinarily be able to afford TEA's professional, technical services.

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